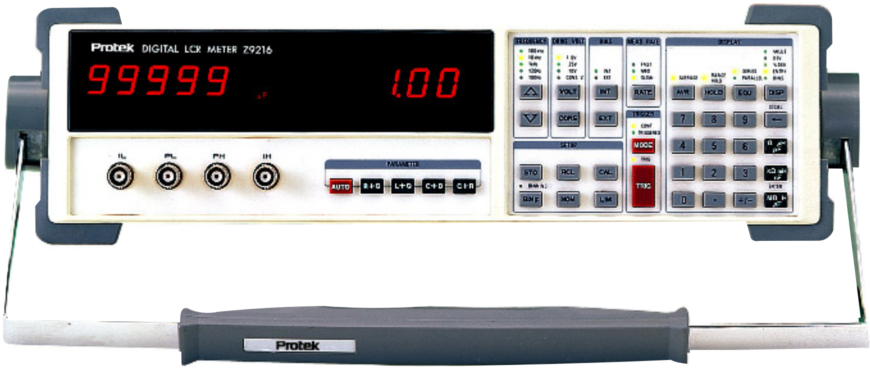
High Accuracy, Wide Range LCR Meter

- 0.2% basic accuracy
- Wide measurement range over13 orders of magnitude
- Store and recall 9 instrument setups
- Measurement rates to 20 times per second
- Test frequencies are 100Hz, 120Hz, 1kHz, 10kHz and 100kHz
- Displays component value and Q or Dissipation factor
- Averaging for 2 to 10 measurements
- RS-232 and optional GPIB and Handler interface
- Open and short circuit compensation for accurate zeroing
- Easy to use and calibrate
- Built-in calibration procedures
- Binning capabilities



Z9216

SPECIFICATIONS

Measured Components
L (inductance)
C (capacitance)
R (resistance)
Measured Circuit Configurations: series and parallel

Measurements
Resistance
Measured Parameter: R + Q
Measurement Ranges: R: 0.0001 Ω to 2000 MΩ
Q: 0.00001 to 50
Inductance
Measured Parameter: L + Q
Measurement Range: L: 0.0001 μH to 99999 H
Q: 0.0001 to 50
Capacitance
Measured Parameters: C + D and C + R
Measurement Range: C: 0.0001 pf to 99999 μF
D: 0.00001 to 10; R: 0.00001 KΩ to 9999 KΩ
Display: Values, % deviation, or bin number

Test Environment
Test Frequencies: 100Hz, 120Hz, 1kHz, 10kHz and 100kHz
Frequency Accuracy: ≤ ±100 PPM
Drive Voltages: Fixed: 0.10, 0.25, 1.0 V RMS;
Vernier: 0.1 to 1.0 V RMS (50 mV resolution)
Drive Voltage Accuracy: ±2%

Measurement Rates:
(For test frequencies of 1kHz or greater):
Slow: 2 measurements/Sec
Medium: 10 measurements/Sec
Fast: 20 measurements/Sec
(For test frequencies of 100Hz and 120Hz):
Slow: 0.6 measurements/Sec
Medium: 2.4 measurements/Sec
Fast: 6 measurements/Sec
Bias Voltage: Internal: +2.0 V DC ±2%;
External: 0 to +40 V DC
Input Protection: 0.25A/250V Fuse
Ranging: Auto or manual
Triggering: Continuous, manual or remote (from the RS-232, GPIB or handler interface)

Measurement Accuracy
Basic Accuracy: ± 0.2% with the following conditions:
1. An ambient temperature of 23°C ±5°C after a 30 minute warm up period.
2. The short and open Cal has been performed.
3. D < 0.1 for capacitance, Q < 0.1 for resistance and Q > 10 for inductance.
The component value, measurement rate and frequency determine the actual measurement accuracy. (See the user manual).
Zeroing Correction: Open and short circuit compensation
Remote Operation: Interfaces: RS-232 (25 pin D female conductor) Standard GPIB and Handler (25 pin D male connector optional)

General Specifications
AC Voltage Input: 120/220 Volts
Frequency: 50/60Hz
Power Consumption: 20 Watts
Operating Temperature: 0 to 50°C at < 80% Relative Humidity
Size: 4.3" H × 14.3" W × 14.5" D
Weight: 18 lbs.
Supplied Accessories: Manual, Line cord, Axial lead adapter
Optional Accessories: GPIB and Handler interface, Kelvin clips, SMD tweezers

Protek Test & Measurement
40 Boroline Road, Allendale, NJ 07401 Tel: 201-760-9898 Fax: 201-760-9888
Website: www.protektest.com E-Mail: sales@protektest.com

High Accuracy, Wide Range LCR Meter

Z9216

Display
- 5 digit primary LED Display for reading component values
- 5 digit secondary display for reading Q, D or R

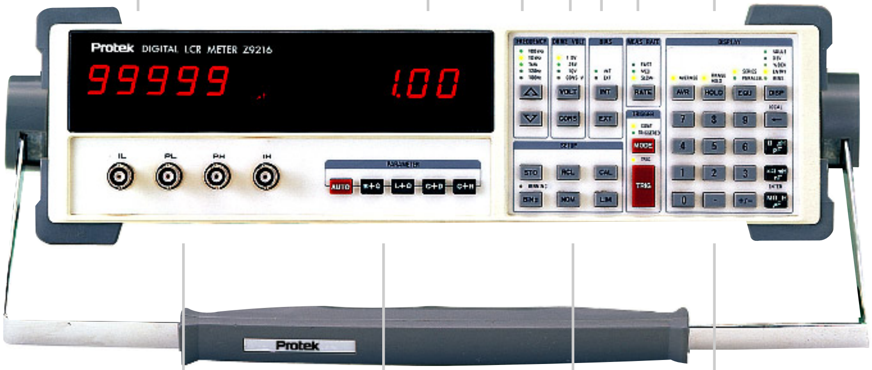
Frequency
Five measurement frequencies (100Hz, 120Hz, 1kHz, 10kHz and 100kHz)

Drive Voltages
4 preset drive voltages from 0.1 to 1V and constant voltage output

Bias
Internal or external bias for measuring capacitors

Meas. Rate
Measurement rates of 2, 10 or 20 measurements per second in continuous or triggered mode

Display
- 2 to 10 measurement average
- Range hold mode
- Series or parallel circuit models
- Display component value, Deviation, % deviation and Bin number displays
- Parameter entry keys



Output terminals
4-wire output: 2 terminals supply the drive signal and 2 terminals for sensing, thereby removing lead error

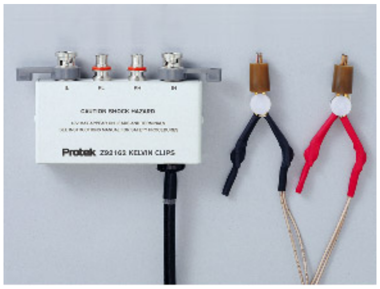
Parameter Keys
Auto key, automatic selection of the appropriate component
- Resistance + Q
- Inductance + Q
- Capacitance + D
- Capacitance + R

Setup
- Store and recall 9 setups
- Binning parameter setup
- Calibration performs open and short calibration
- Standard calibration
- Internal self-tests
- Vernier amplitude drive voltages from 0.1 to 1V in 50mV increments
- Setting settling time

Numeric keyboard
For entering measurement conditions and values.

ACCESSORIES

The standard accessory supplied with the Z9216. This unit adapts to the Z9216 input BNC terminals and facilitates easy measurement of Axial or Radial lead components.



The Kelvin clips provide a 4-wire connection to components that have large or odd shaped leads. This removes any error caused by voltage drops in the leads.

The SMD tweezers are used to measure small surface mount or odd shaped components.

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Z9216

MANUAL VOL 2

High Accuracy, Wide Range LCR Meter

Protek Z9216

High Accuracy, Wide Range LCR Meter

Protek

Chapter

1

Background on Components and Measurements

Properties of Resistors, Inductors, and Capacitors

The measurements made by the Model Z9216, Digital LCR Meter are based on the definitions of impedance and the properties of discrete components designed to provide impedances in electronic circuits.

Definitions of Resistive and Reactive Parameters

Let the sinusoidal voltage and current in an electronic circuit at a particular frequency, f be represented in the complex or phasor notation, given by

$$V(t) = |V| \cos(\omega t + \theta_v) \quad (1a)$$

$$= |V| e^{j(\omega t + \theta_v)} = \left(|V| e^{j\theta_v}\right) e^{j\omega t} \quad (1b)$$

$$I(t) = |I| \cos(\omega t + \theta_i) \quad (2a)$$

$$= |I| e^{j(\omega t + \theta_i)} = \left(|I| e^{j\theta_i}\right) e^{j\omega t} \quad (2b)$$

where $j = \sqrt{-1}$, $\omega = 2\pi f$, and θ_v and θ_i are symbols for phases of the voltage and current relative to the frequency f. The impedance of a circuit component is defined as the complex number Z, in ohms, that gives the ratio of the voltage across the component to the current in the component:

$$Z = Z(\omega) = \frac{V(t)}{I(t)} = \frac{|V| e^{j(\omega t + \theta_v)}}{|I| e^{j(\omega t + \theta_i)}} = \frac{|V|}{|I|} e^{j(\theta_v - \theta_i)} \quad (3)$$

Component Categories

From equation (3), we observe that if the phases of the voltage across the component and the current in it are equal, then the impedance is a real number:

$$Z = \frac{|V|}{|I|} e^{j(0)} = \frac{|V|}{|I|} \quad (4)$$

In this situation, the impedance is purely *resistive*, as an ideal resistor would be.

If the phase of the voltage is 90 degrees ($\pi/2$ radians) ahead of the phase of the current, then the impedance is a positive imaginary number:

$$Z = \frac{|V|}{|I|} e^{j(\pi/2)} = j\frac{|V|}{|I|} \quad (5)$$

In this situation of positive, imaginary impedance, the impedance is purely *inductive*, as an ideal inductor would be. The impedance of an ideal inductor with inductance L is a linear function of frequency, given by $Z_L = j\omega L$.

If the phase of the voltage is 90 degrees (π/2 radians) behind the phase of the current, then the impedance is a negative imaginary number:

$$Z = \frac{|V|}{|I|} e^{j(-\pi/2)} = -j\frac{|V|}{|I|} \qquad (6)$$

In this situation of negative, imaginary impedance, the impedance is purely *capacitive*, as an ideal capacitor would be. The impedance of an ideal capacitor with capacitance C is the inverse of a linear function of frequency, given by $Z_C = 1 / j\omega C = -j / .\omega C$.

Actual circuit components are not purely resistive, inductive, or capacitive. From a practical standpoint, capacitors and inductors have impedances with resistive parts, and their impedances may not be linear functions of frequency or independent of the voltage. The general expression for impedance, considers a real part containing the resistive component of the entire impedance, R, and the reactance or imaginary part of the impedance, being X_l, Xc, or the algebraic sum of the two. This complex impedance is represented by:

$$Z = R + jX, \qquad (7)$$

Where $X = \omega L$ for an inductor and $X = -1/\omega C$ for a capacitor. Since the quantity X is traceable to the ratio of a voltage to a current, it is expressed in ohms. Often, it is desirable to express the impedance in ohms as a scalar (real) quantity; in that case, its magnitude $|Z| = \sqrt{R^2 + X^2}$ is used.

Units

The unit of resistance is the ohm, with the symbol Ω (omega). A 1-Ω resistor drops 1 volt across its terminals when one Ampere is flowing through the resistor.

The unit of inductance is the Henry, with the symbol H. For a one-amp AC current, a 1-H inductor would produce an AC voltage across it whose magnitude is numerically equal to 2π times the frequency in Hertz.

The unit of capacitance is the Farad, with the symbol F. For a one-amp AC current, a 1-F capacitor would produce an AC voltage across it whose magnitude is numerically equal to the inverse of 2π times the frequency in Hertz.

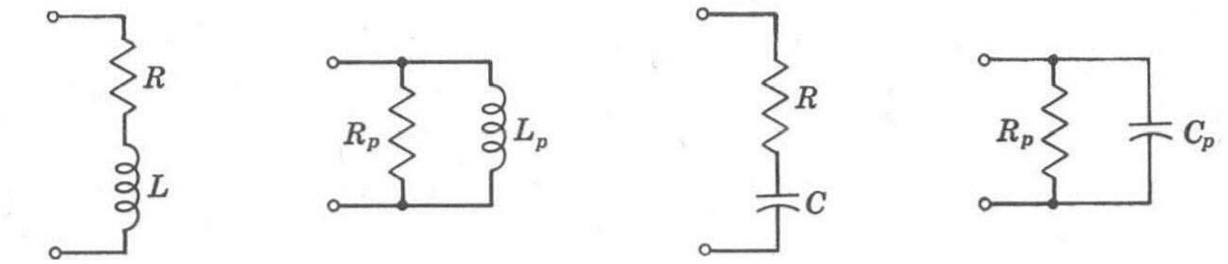
Series and Parallel Equivalent Circuits

The impedances of Actual resistors, inductors and capacitors are combinations of resistance, inductance, and capacitance. The simplest models for actual inductors and capacitors are the series and parallel equivalent circuits shown in Figure 1-1.

For example, the complex impedance of an inductor is

$$Z = R + jX = R + j\omega L \qquad \text{(series equivalent circuit)} \qquad (8a)$$

$$= \frac{R_p \cdot j\omega L_p}{R_p + j\omega L_p} = \frac{R_p + jR_p\left(R_p / \omega L_p\right)}{1 + \left(R_p / \omega L_p\right)^2} \qquad \text{(parallel equivalent)} \qquad (8b)$$



8a - Inductor Series Equivalent | 8b - Inductor Parallel Equivalent | 9a -Capacitor Series Equivalent | 9b - Capacitor Parallel Equivalent

Figure 1-1 Equivalent circuits for inductors and capacitors.

The complex impedance of a capacitor is

$$Z = R + jX = R - j / \omega C \qquad \text{(series equivalent circuit)} \qquad (9a)$$

$$= \frac{R_p \cdot 1 / j\omega C_p}{R_p + 1 / j\omega C_p} = \frac{R_p}{1 + j\omega C_p R_p} = \frac{R_p\left(1 - j\omega C_p R_p\right)}{1 + \left(\omega C_p R_p\right)^2} \qquad \text{(parallel equivalent)} \qquad (9b)$$

Quality Factor

Originally, the quality factor, Q was defined for an inductor as a measure of the efficiency of energy storage in the inductor when an AC current is passed through it. Mathematically, the definition is[1]

$$Q = 2\pi \text{ (max. energy stored)} \div \text{(energy dissipated per Hz)} \qquad (10a)$$

$$= 2\pi f \text{ (max. energy stored)} \div \text{(average power dissipated)} \qquad (10b)$$

Since the average power dissipated in the inductor with series resistance R is $|I|^2R$ and the maximum energy stored in the inductor is $L|I|^2$, the quality factor for an inductor is given by

$$Q = \omega L \,/\, R. \qquad (11a)$$

By equating (8a) and (8b), the series equivalent circuit parameters R and L can be expressed in terms of the parallel parameters R_p and L_p. When that is done and substituted in equation (10a), we find that the quality factor also is written

$$Q = R_p \,/\, \omega L_p. \qquad (11b)$$

While the concept of the quality factor was originally applied to inductors, it may be extended so that the efficiency of energy storage in a capacitor may be expressed in terms of the circuit components and frequency. Thus, if the series resistance and capacitance of a capacitor are, respectively, R and C as in Figure 1-1, then (10b) is evaluated to be

$$Q = 1 \,/\, \omega CR. \qquad (12a)$$

By equating (9a) and (9b), the series equivalent circuit parameters R and C can be expressed in terms of the parallel parameters R_p and C_p. When that is done and substituted in equation (12a), we find that the quality factor for a capacitor also is written

$$Q = \omega C_p \, R_p. \qquad (12b)$$

---

[1] W. L. Everett and G. E. Anner, *Communication Engineering*, McGraw-Hill, New York, 1956.

Using the quality factor, the impedance of an inductor is seen to be

$$Z = R + j\omega L = R(1 + jQ) = \omega L(j + 1/Q) \qquad (13a)$$

and the inductor's series equivalent circuit components can be expressed in terms of its parallel equivalent circuit components as

$$R = \frac{R_p}{1+Q^2}, \qquad L = \frac{Q^2 L_p}{1+Q^2} \qquad (13b)$$

The impedance of a capacitor in terms of the quality factor is

$$Z = R + 1/j\omega C = R(1 - jQ) = \frac{1}{\omega C}(D - j) \qquad (14a)$$

and the capacitor's series equivalent circuit components can be expressed in terms of its parallel equivalent circuit components as

$$R = \frac{R_p}{1+Q^2}, \qquad C = (1 + D^2)C_p \qquad (14b)$$

Chapter
2

Accuracy and Calibration

How to Assess and Control the Accuracy

The accuracy achieved by the Model Z9216 Digital LCR Meter depends on several factors. In this chapter, equations are given for estimating the accuracy of a specific measurement, and procedures are given for calibrating the meter.

Accuracy Specifications

Note: The accuracy of the Model Z9216 that is stated in this chapter is valid for the following conditions: (a) a warm-up time of at least 30 minutes, (b) a temperature of 23°C ± 5°C, (73°F± 9°F) (c) the use of the built-in fixture, and (d) the completion of the open and short circuit calibrations. In addition, the component being measured must have the following characteristic: D < 0.1 for a capacitor, Q < 0.1 for a resistor, or Q > 10 for an inductor.

General Accuracy Equation

The accuracy of a measurement is a function of the “basic impedance accuracy” at the specific frequency, measurement rate, signal amplitude, and the impedance of the device under test (DUT) relative to the measurement range. The basic instrument accuracy can be determined from graphs given below. Additional factors affecting the accuracy are related to the measurement conditions and the impedance of the DUT. From these, the accuracy of a particular measurement in its optimal range is calculated. See below for the effects on measurements made out of an optimal range.

The basic equation for impedance measurement accuracy equation is given by:

$$A_{z(measured)}\,\% = \pm\,[A_Z \times K_i \times K_v + 100 \times (K_h + K_l)], \text{ where} \qquad (1)$$

A_Z = the basic impedance accuracy from Figure 2-1, which should be multiplied by two if the unit is in constant voltage mode. Figure 2-1 is based on the fact that the best accuracy occurs when the impedance to be measured is greater than ¼ the source resistance and less than 4 times that resistance, and when the test frequency is 1 kHz or less.

K_i = integration time factor, as given in Table 2-1.

K_v = drive voltage error factor, as given in Table 2-2. Note from Table 2-2 that K_v is defined as equal to 1.0 for the primary drive voltages (1.0, 0.5, and 0.25 Vrms).

K_h, K_l = extreme range error terms, as given in Table 2-3. Note from Table 2-3 that K_l is negligible for impedances above 100 Ω and K_h is negligible for impedances below 1 kΩ, both at all frequencies.

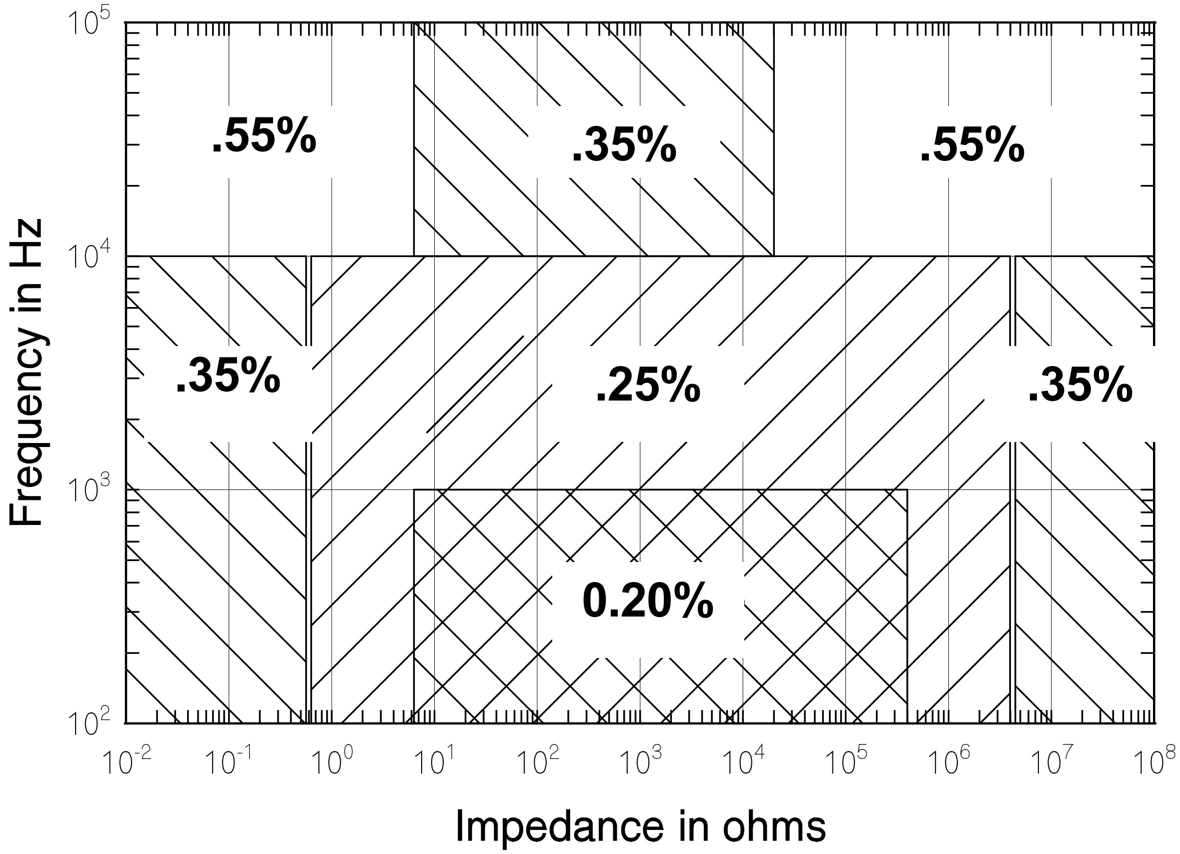


Figure 2-1 Basic Impedance Accuracy

Table 2-1 - Integration Time Accuracy Factor, K_i

Meas. Rate	Frequency	Z_m	K_i
Slow, Medium	All	All	1
Fast	100 Hz to 1 kHz	6.25 Ω < Z_m < 400 kΩ	3
	All other		2

Table 2-2 - -Drive Voltage Error Factor, K_v

Vout (Vrms)	K_v
0.55 to 1.0	1/Vout
0.3 to 0.5	0.5/Vout
0.15 to 0.25	0.25/Vout
0.10	0.11/Vout

Table 2-3 - Extreme Range Error Terms For Impedance and Resistance, K_h and K_l

Frequency	K_l	K_h
100 Hz, 120 Hz, 1 kHz	$(1\ m\Omega/Z_m)$	$(Z_m/2\ G\Omega)$
10 kHz	$(1\ m\Omega/Z_m)$	$(Z_m/1.5\ G\Omega)$
100 kHz	$(4\ m\Omega/Z_m)$	$(Z_m/50\ M\Omega)$

Accuracy Equations for Specific Measurement Modes

R + Q Accuracy

In the R + Q measurement mode, the basic impedance accuracy, Az, in equation (1), may be read from Figure 2-1 directly while interpreting the "impedance" as "resistance." The resistance accuracy is calculated from equation (2a), with the additional stipulation that if the measured Q has an absolute value greater than 0.1, then the basic resistance accuracy factor should be multiplied by the factor (1 + |Q|).

$$A_{r(measured)}\ \% = \pm [A_r \times K_i \times K_v + 100 \times (K_h + K_l) \qquad (2a)$$

Where $A_{r(measured)}$ % is the measured or published resistance accuracy and A_r is the basic resistance accuracy. The basic resistance accuracy, A_r, which can be taken from Figure 2-1 by substituting impedance, Z, with resistance, R.

With the basic resistance accuracy factor denoted A_r. The accuracy of the measurement of Q is given by:

$$\text{Accuracy of Q} = \pm [(A_r/100) \times (1+Q^2)] \qquad (2b)$$

Note that the accuracy of Q is specified as a magnitude, *not* as a percentage.

L+Q Accuracy

The basic impedance accuracy depicted in Figure 2-1 applies to inductance measurements when the impedance is interpreted to be $2\pi f L$, where f is the test frequency in Hz and L is the inductance in Henrys. For convenience, Figure 2-1 is redrawn as Figure 2-2 with lines of constant inductance superimposed. Also, Table 2-3 is recreated for inductive impedances and named as Table 2-4. Note from Table 2-4 that the range error factor K_l is negligible for inductances above $15.9/f$ H and K_h is negligible for inductances below $159/f$ H.

The accuracy of the inductance measurement, $A_{l\ (measured)}$, is calculated by applying equation (3a), with the additional stipulation that if the measured Q has an absolute value less than 10, then the basic inductance accuracy factor, A_l, should be multiplied by the factor (1 + |1/Q|).

$$A_{l\ (measured)}\ \% = \pm [\ A_l \times K_i \times K_v + 100 \times (K_h + K_l)] \qquad (3a)$$

Then the accuracy of the Q calculation is given by equation (3b)

$$\text{Accuracy of Q} = \pm [(A_l/100) \times (1+Q^2)] \qquad (3b)$$

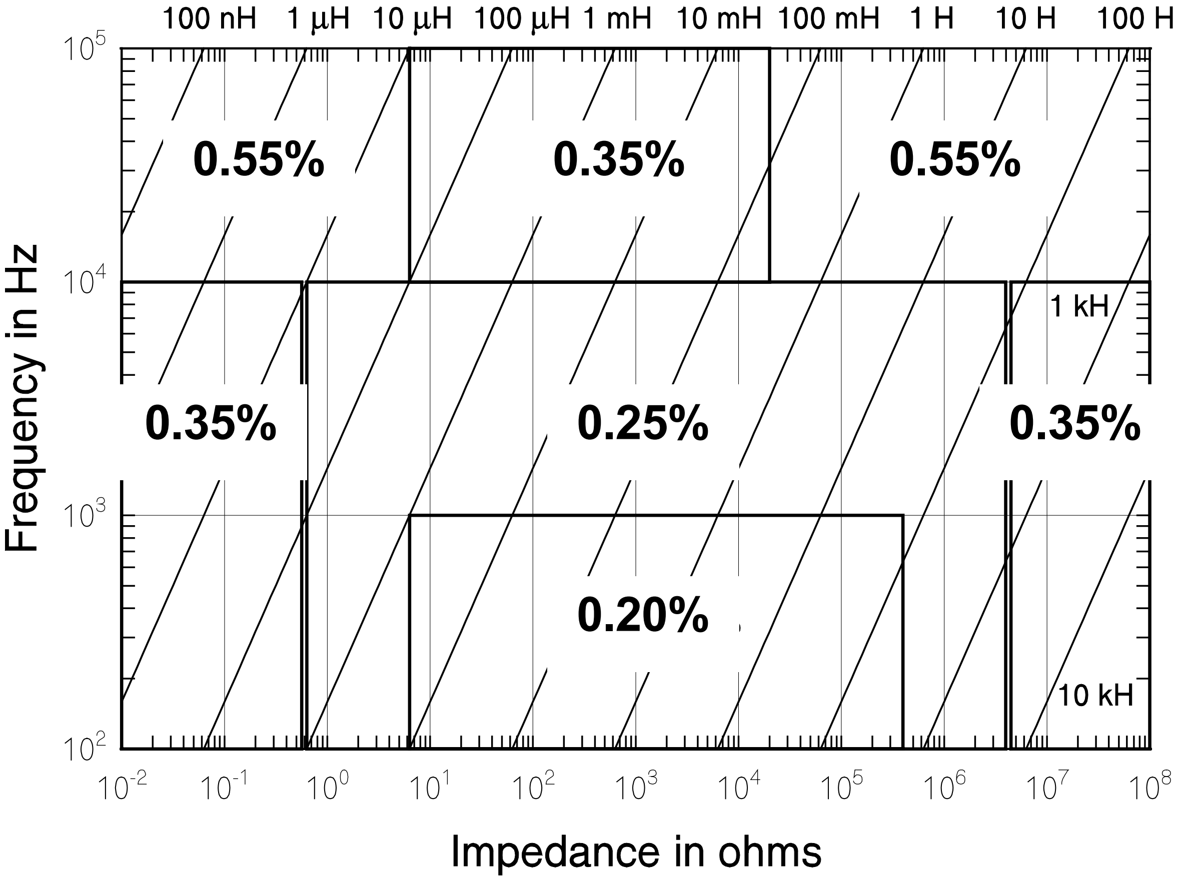


Figure 2-2 Basic Impedance Accuracy for Inductance

Table 2-4 - Extreme Range Error Terms for Inductances, K_h and K_l

Frequency	K_l	K_h
100 Hz, 120 Hz	(1 µH/L_m)	(L_m/2.6 MH)
1 kHz	(0.1 µH/L_m)	(L_m/260 kH)
10 kHz	(0.02 µH/L_m)	(L_m/10 kH)
100 kHz	(0.02 µH/L_m)	(L_m/100 H)

Note: L_m = Measured Inductance Value

C+D Accuracy

The basic impedance accuracy depicted in Figure 2-1 applies to capacitance measurements when the impedance is interpreted to be $1/2\pi f C$, where f is the test frequency in Hz and C is the capacitance in Farads. For convenience, Figure 2-1 is redrawn in Figure 2-3 with lines of constant capacitance superimposed. Also, Table 2-3 is recreated for capacitive impedances as Table 2-5. Note from Table 2-5 that the range error factor K_l is negligible for capacitances below $1590/f$ µF and K_h is negligible for capacitances above $159/f$ µF.

The accuracy of the capacitance measurement is calculated from equation (1) above, with the additional stipulation that if the measured D has a value less than 0.1, then the basic capacitance accuracy factor should be multiplied by the factor (1 + D). Let the basic capacitance accuracy factor be denoted A_c.

$$A_{c\,(measured)}\ \% = \pm [\, Ac \times K_i \times K_v + 100 \times (K_h + K_l)] \qquad (4a)$$

Then the accuracy of the D calculation is given by

$$\text{Accuracy of } D = \pm [A_c/100] \qquad (4b)$$

Note that the accuracy of D is specified as a magnitude, *not* as a percentage.

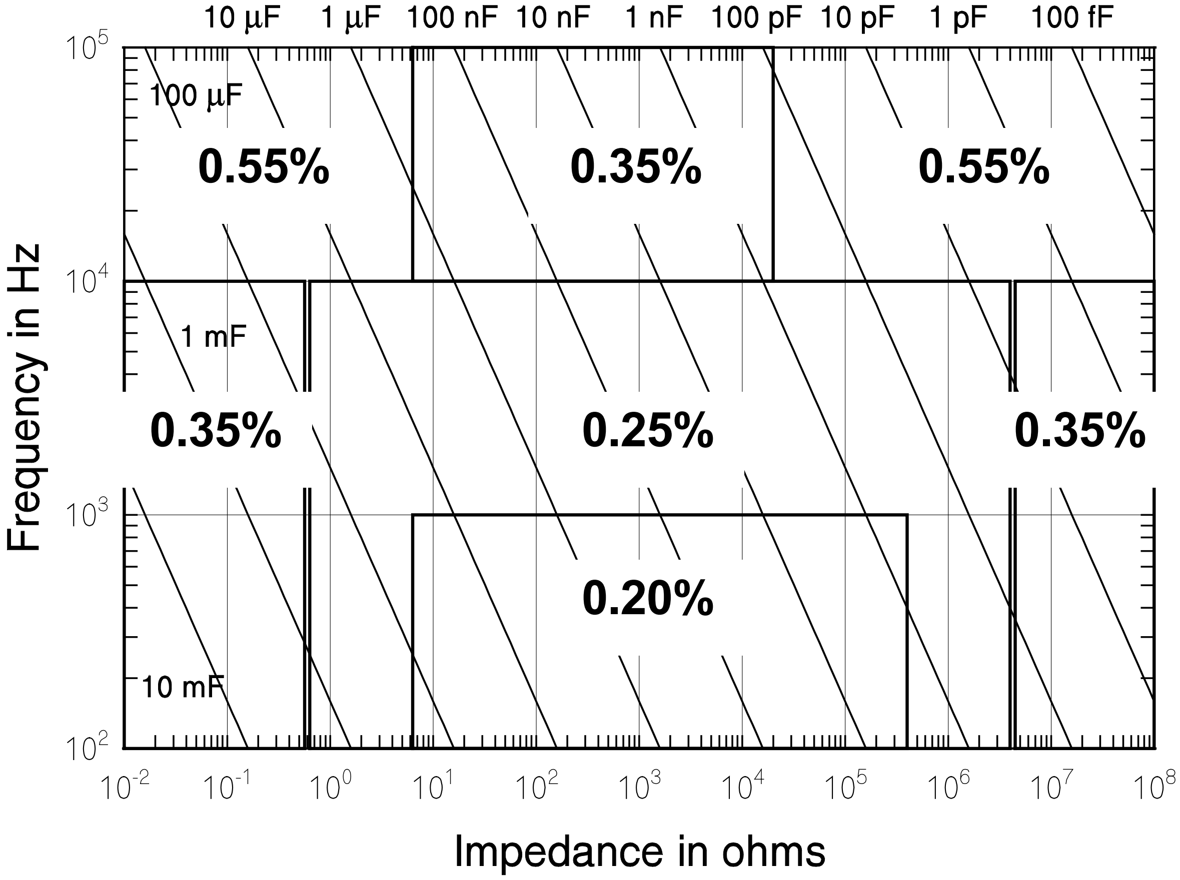


Figure 2-3 Basic Impedance Accuracy for Capacitances

Table 2-5 Extreme Range Error Terms for Capacitances (C + D mode), K_h and K_l

Frequency	K_l	K_h
100 Hz, 120 Hz	(2 pF/C_m)	(C_m/1600 mF)
1 kHz	(0.1 pF/C_m)	(C_m/160 mF)
10 kHz	(0.01 pF/C_m)	(C_m/16 mF)
100 kHz	(0.02 pF/C_m)	(C_m/200 μF)

Note: C_m = Measured Capacitance Value

Table 2-6 - Extreme Range Error Terms for Capacitances (C + R mode), K_h and K_l

Frequency	K_l	K_h
100 Hz, 120 Hz	(2 pF/C_m)	(C_m/2000 mF)
1 kHz	(0.1 pF/C_m)	(C_m/200 mF)
10 kHz	(0.01 pF/C_m)	(C_m/10 mF)
100 kHz	(0.01 pF/C_m)	(C_m/100 μF)

C+R Accuracy

The basic impedance accuracy depicted in Figure 2-1 applies to capacitance measurements when the impedance is interpreted to be $1/2\pi f C$, where f is the test frequency in Hz and C is the capacitance in Farads. For convenience, Figure 2-1 is redrawn in Figure 2-3 with lines of constant capacitance superimposed. Also, Table 2-3 is recreated for capacitive impedances in the C + R measurement mode as Table 2-6. Note from Table 2-6 that the range error factor K_l is negligible for capacitances below $1590/f$ μF

For small values of D (D < 0.1), the accuracy of the capacitance measurement in the C + R mode is calculated from equation (4a) above, and the accuracy of the resistance measurement is given by

$$\text{Accuracy of R in \%} = \pm [A_c \times (1 + 1/D)] \qquad (5a)$$

where A_c is the accuracy of the capacitance measurement and

$$D = R/2\pi f C. \qquad (5b)$$

For D > 0.1, the impedance accuracy must first be calculated. To do this, first calculate the impedance of the DUT by adding the resistive and capacitive elements, either in series or parallel, as appropriate. Use the impedance accuracy graph to obtain an impedance accuracy, and let it be denoted A_z. The accuracies of C and R are calculated from the impedance accuracy as follows:

$$\text{Accuracy of C in \%} = \pm [A_z \times (1 + |D|)] \quad (6)$$

$$\text{Accuracy of R in \%} = \pm [A_z \times (1 + 1/|D|)] \quad (7)$$

Accuracy When Holding a Nonoptimal Range

When a component is measured outside of its nominal range (in range hold), the accuracy of the measurement is reduced. The nominal ranges are defined as approximately four times above and below the nominal impedance value:

Range	Nominal Impedance Range
R3	6.25 Ω to 100 Ω
R2	100 Ω to 1.6 kΩ
R1	1.6 kΩ to 25.6 kΩ
R0 (100 Hz to 10 kHz)	25.6 kΩ to 400 kΩ

(R0 is not defined for 100 kHz.) Components that are measured while auto ranging have only one set of extreme range terms (K_h, K_l) per frequency.

For components measured in the range hold mode, the values of K_h and K_l are different for each range. These values are calculated from parameters tabulated below in Tables 2-7 to 2-9 for resistive, inductive, and capacitive measurements, respectively.

Table 2-7 - Parameters for Calculating K_l and K_h for Resistive Measurements

	$R_l = K_l \times Z_m$				$R_h = K_h \times Z_m$			
Frequency	R3	R2	R1	R0	R3	R2	R1	R0
100, 120, 1 kHz	1 mΩ	0.02 Ω	0.2 Ω	4 Ω	400 kΩ	6.5 MΩ	100 MΩ	2 GΩ
10 kHz	1 mΩ	0.02 Ω	0.2 Ω	4 Ω	400 kΩ	6.5 MΩ	100 MΩ	1.5 GΩ
100 kHz	4 mΩ	0.03 Ω	0.4 Ω	---	200 kΩ	3 MΩ	50 MΩ	---

Table 2-8 - Parameters for Calculating K_l and K_h for Inductive Measurements

	$L_l = K_l \times L_m$				$L_h = K_h \times L_m$			
Frequency	R3	R2	R1	R0	R3	R2	R1	R0
100, 120 Hz	1 µH	20 µH	300 µH	5 mH	630 H	10 kH	160 kH	2.6 MH
1 kHz	1 µH	20 µH	300 µH	5 mH	630 H	10 kH	160 kH	2.6 MH
10 kHz	1 µH	20 µH	300 µH	5 mH	630 H	10 kH	160 kH	2.6 MH
100 kHz	1 µH	20 µH	300 µH	5 mH	630 H	10 kH	160 kH	2.6 MH

Table 2-9 - Parameters for Calculating K_l and K_h for Capacitive Measurements

	$C_l = K_l \times C_m$				$C_h = K_h \times C_m$			
Frequency	R3	R2	R1	R0	R3	R2	R1	R0
100, 120 Hz	4 nF	240 pF	16 pF	2 pF	1600 mF	80 mF	6.7 mF	400 µF
1 kHz	400 pF	24 pF	1.6 pF	0.1 pF	160 mF	8 mF	670 µF	40 µF
10 kHz	40 pF	2.4 pF	0.16 pF	0.01 pF	16 mF	800 µF	40 µF	2.6 µF
100 kHz	8 pF	2.4 pF	0.02 pF	---	200 µF	80 µF	4 µF	---

Verification of Meter Performance

The performance verification procedures in this section test and verify the performance of Model Z9216 and compare it to the specifications listed in Volume 1 of the User's Manual. The first set of tests verifies the basic functionality of the unit. The second set of tests verifies the critical specifications of the Model Z9216. The results of each section can be recorded on the test sheets located at the end of this manual.

Functional Tests

These simple tests verify the basic functionality of the Model Z9216. They are not intended to verify the accuracy of the unit.

Necessary Equipment:

Item	Critical Specifications	Recommended Model
Analog Oscilloscope with × 10, 10MHz probes	100MHz Bandwidth	Tektronix 2445
24.9 Ω Resistor	0.1%	Dale CMF55 or equivalent
402 Ω Resistor	0.1%	Dale CMF55 or equivalent
6.34 kΩ Resistor	0.1%	Dale CMF55 or equivalent
100.0 kΩ Resistor	0.1%	Dale CMF55 or equivalent
22 nF Capacitor	1% NPO	Murata Erie RPE series or equivalent

Front Panel Test

This test verifies the front panel display digits, LEDs, and keypad.

1. Turn on the unit while holding down the **DISP** key. A single segment in the third digit of the left display should be on.
2. Press the down arrow key ↓ to light each segment (seven total) and the decimal for the third and fourth digits of the left display, for a total of 16 segments. Only one segment or decimal point should be on at a time. (Pressing the up arrow key ↑ will step backward through the pattern.)
3. Press the down arrow key ↓ again (17th time) to light all the segments of all 12 digits. The AUTO LED will also be on.
4. Press the down arrow key ↓ repeatedly to light the 25 LEDs in the display and the 26 LEDs on the keypad. The LEDs turn on one at a time, from top to bottom and left to right, first for the display, and then for the keypad. Only one LED should be on at a time.
5. After all of the LEDs have been tested, further pressing of the front panel keys will display the key code associated with each key. Each key has a different key code, starting with 01 at the upper left, and increasing from top to bottom then left to right.
6. The unit must be switched off to leave this mode.

Self Tests

The internal self-tests verify the functionality of the Model Z9216. Turn on the unit. The ROM program and model name will be displayed for about three seconds. Next the message "tESt....' will be displayed while the unit performs its self tests. After the tests are completed the unit should display 'tESt PASS' to indicate that the tests were successful. If not, an error message will appear. See the TROUBLESHOOTING section for a description of the error messages.

Output Voltage

This test checks the Model Z9216 output voltage for the correct frequency and amplitude.

1. Set the Model Z9216 to 1 kHz, 1 V and constant voltage. Set the scope to 1 V/div vertical and 0.5 ms/div horizontal. Connect a ×10 probe to the scope.
2. Place the tip of the probe into the "+" side of the fixture and connect the ground clip to the center guard.
3. The scope should display a sine wave that occupies two divisions horizontally and about 5.5 divisions peak to peak vertically (1.0 Vrms - 2.83 V peak to peak). There should be no irregularities in the waveform.
4. Change the amplitude setting of the Model Z9216 to 0.25 and 0.10 V in succession and verify that the output is within 2% of nominal.
5. Set the amplitude back to 1.0 V. Change the Model Z9216 and scope settings to verify that the output at 100 Hz, 120 Hz, 10 kHz and 100 kHz is within 2% of nominal.

Resistance Measurement

This test verifies that the Model Z9216 operates and is able to measure a component in each of its ranges. The readings obtained should be within ±(tolerance of the component + tolerance of the Model Z9216).

1. Press the key sequence **RCL 0 ENTER** to put the unit in its default setup.
2. Perform open and short circuit calibrations for the fixture configuration to be used. See Volume 1 for details on these null calibrations.
3. Set the unit to the R+Q measurement mode, series equivalent circuit, and 1 kHz test frequency. Install the 24.9 Ω resistor.
4. Verify that the meter reads the resistance correctly to within ±0.15%. Verify that Q is a small value, about +0.0001 or smaller. Install the 402 Ω resistor. Verify that the meter reads the resistance correctly to within ±0.15%. Verify that Q is a small value, about +0.0001 or smaller.
5. Change the equivalent circuit to parallel. Install the 6.34 kΩ resistor. Verify that the meter reads the resistance correctly to within ±0.15%. Verify that Q is a small value, about –0.0001 or smaller.
6. Install the 100 kΩ resistor. Verify that the meter reads the resistance correctly to within ±0.15%. Verify that Q is a small value, about –0.0002 or smaller.

Capacitance Measurement

This test verifies that the Model Z9216 is able to measure components at different frequencies. The limits of the readings are the same as before: ± (component tolerance + meter tolerance).

1. If the fixture configuration has changed, perform open and short circuit calibration.
2. Set the Model Z9216 to the C+D measurement mode, parallel equivalent circuit, and 1 kHz test frequency.
3. Install the 22 nF capacitor. Verify that the unit reads the capacitance correctly to within 1.10%. Verify that D is below 0.0001.
4. Set the unit to 100 Hz. Verify that the capacitance reading is close to the value measured above and within the tolerance stated above. Repeat for 120 Hz. D values should be below 0.0001.
5. Repeat for 10 kHz. At 10kHz, the tolerance is 1.15%. For 100 kHz the tolerance is 1.25%. D values should be below 0.001 for 10 kHz and 0.01 for 100 kHz.

Performance Tests

These tests are intended to measure the Model Z9216's conformance with its published specifications. These test results, along with the results of the functional tests, can be recorded on the test sheet at the end of this manual.

Necessary Equipment

Instrument	Critical Specifications
Time Interval Counter	Time Interval Accuracy: 1 ns max
DC/AC Voltmeter	5 ½ digit DC accuracy, true RMS AC to 100 kHz
Resistance decade box	Accuracy 0.02%: 1 Ω to 1 MΩ
Capacitance decade box	Accuracy 0.02%: 1000 pF to 10 μF

Test conditions: at least 30 minutes of warm-up time, and a temperature in the range of 23°C ± 5 °C (73°F ± 9 °F).

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Frequency Accuracy

This test measures the accuracy of the different output frequencies. They should be within 0.01% (100 ppm) of the nominal value.

1. Set the Model Z9216 to its default conditions by pressing the key sequence **RCL 0 ENTER**. Set the unit to constant voltage mode, 1 kHz test freqency, and remove any part from the fixture.
2. Install the BNC adapter on the fixture. Connect the IH lead to the frequency counter.
3. Verify that the frequency counter reads 1 kHz ± 0.1 Hz (+0.01%). Record the result.
4. Repeat step 3 at 100 Hz, 120 Hz, 10k Hz and 100 kHz. The frequencies should all be within 0.01% of the nominal frequency. Record the results.

Amplitude Accuracy

This test measures the amplitude accuracy of the drive output. It should be within 2.0% of the nominal value for all of the amplitude settings.

1. Connect the AC/DC voltmeter across the two sides of the fixture. A small piece of wire inserted in each side of the fixture is a convenient way to connect the DVM. Do not connect either end to ground. Set the DVM to AC volts, auto ranging.
2. Set the Model Z9216 to its default conditions by pressing the key sequence **RCL 0 ENTER**. Set the unit to constant voltage mode. The output voltage should be 1.0 Vrms at 1 kHz. Verify that the voltage reading is between 0.98 and 1.02 Vrms. Record the result.
3. Repeat step 2 for 100 Hz, 120 Hz, and 100 kHz. All voltage readings should be between 0.98 and 1.02 Vrms. Record the results.
4. Set the frequency to 1 kHz. Set the voltage sequentially to 0.25V and 0.10V. The DVM should read within 2.0% of the nominal values (between 0.245 and 0.255 and between 0.098 and 0.102, respectively). Record the results.
5. Set the DVM to DC volts. Set the Model Z9216 to the C+D measurement mode, 100 kHz test frequency, 0.10 V drive voltage with internal Bias on. Verify that the DC voltage is 2.0 VDC ± 2%.

Impedance Accuracy

These tests confirm that the Model Z9216 meets its impedance measurement accuracy specification. Precision impedance standards are required. The minimum and maximum acceptable values are determined by adding the tolerance of the Model Z9216 and that of the standard. For example, for 1.000 kΩ @ 1 kHz, the basic meter tolerance is ±0.20%, the tolerance of the resistance standard is ±0.02%, and thus the total tolerance is ±0.22% or ±02.2 Ω. So the range of acceptable values is 997.8 Ω to 1002.2 Ω. If standards with different tolerances are used, the acceptable limits will have to be calculated and adjusted. The sheets at the end of this manual contain blank columns so that the verifying technician may add custom ranges based on the accuracy of the resistance decade box used..

Resistance Accuracy

1. Connect the Fixture Adapter to the Model Z9216. Install a BNC to stacking banana plug adapter on the end of each BNC cable. Tape over (or cut off) the ground leads of the plugs connected to the orange (PH) and purple (PL) cables. Connect the ground leads of the red (IH) and blue (IL) cables to the case ground of the decade box. Plug the orange, (PH) and purple, (PL) signal leads to the "+" and "–" terminals on the decade box. Plug the red signal lead, (IH) into the orange signal lead and plug the blue, (IL) signal lead into the purple signal lead. Set the Model Z9216 to its default conditions by pressing **RCL 0 ENTER**, then press the **R+Q** key and set the test frequency to 1 kHz.
2. Unplug the red/orange lead pair from the "+" terminal of the decade box and plug them into the blue/purple lead pair. Perform short circuit calibration. Remove the red/orange lead pair form blue/purple lead pair and locate them at the same separation from the blue/purple pair as they will be during operation. Perform open circuit calibration.
3. Connect the red/orange lead pair to the "+" terminal of the decade box. Set the dials to all zeros. Note the resistance value that the Model Z9216 measures. This is the resistance of the switch contacts and connectors. Enter this as a relative value in the entry display. Set the Model Z9216 to the DEV display mode.

4. Set the decade resistor and the Model Z9216 according to the values in the Resistance Accuracy Table below. Verify that the readings fall within the acceptable values. Record the results.

Resistance Accuracy Table

Resistance	Range	Conditions	Minimum	Maximum
10.0Ω	3	1kHz, Series	9.978	10.022
25.0Ω	3	1kHz, Series	24.945	25.055
25.0Ω	3	10kHz, Series	24.933	25.067
25.0Ω	3	100kHz, Series	24.908	25.092
100.0Ω	3	1kHz, Series	99.78	100.22
100.0Ω	2	1kHz, Series	99.78	100.22
400.0Ω	2	1kHz, Series	399.12	400.88
400.0Ω	2	10kHz, Series	398.92	401.08
400.0Ω	2	100kHz, Series	398.52	401.48
1.600KΩ	2	1kHz, Parallel	1596.48	1603.52
1.600 KΩ	1	1kHz, Parallel	1596.48	1603.52
6.400 KΩ	1	1kHz, Parallel	6385.92	6414.08
6.400 KΩ	1	10kHz, Parallel	6382.72	6417.28
6.400 KΩ	1	100kHz, Parallel	6376.32	6423.68
25.000 KΩ	1	1kHz, Parallel	24945	25055
25.000 KΩ	0	1kHz, Parallel	24945	25055
100.000 KΩ	0	1kHz, Parallel	99780	100220
100.000 KΩ	0	10kHz, Parallel	99730	100270
400.000 KΩ	0	1kHz, Parallel	399120	400880

*** if the Q value is greater than 0.1, the allowed tolerance must be multiplied by (1+Q)**

Capacitance Accuracy

1. Connect the adapter ground leads of IH and IL to ground terminal of the decade capacitor. Connect the IH and PH leads to the “+” terminal of the decade capacitor. Connect the IL and PL leads to the "–" terminal of the decade capacitor box. Set the Model Z9216 to its default conditions by pressing the key sequence **RCL 0 ENTER**, then select the R+Q measurement mode and the 1 kHz test frequency.
2. Unplug the IH, PH leads from "+" terminal of the decade capacitor box and plug them into the "–" terminal of the decade capacitor box. Perform short circuit calibration. Unplug the IH, PH leads from "–" terminal of the decade capacitor box, then perform open circuit calibration.
3. Connect the IH, PH leads to the "+" terminal of the decade capacitor box. Set the capacitance to zero.
4. Note the capacitance value the Model Z9216 measures. This is the capacitance of the switch contacts and connectors. Enter this as a relative value in the entry display. Set the Model Z9216 to the DEV display mode.
5. Set the decade capacitor and the Model Z9216 according to the values in the Capacitance Accuracy Table below. Verify that the readings fall within the acceptable values. Record the results.

Capacitance Accuracy Table

Capacitance	Frequency	Range	Minimum	Maximum
1.0 nF	1 kHz	0	.99780 nF	1.0022 nF
1.0 nF	10 kHz	1	.99730 nF	1.0027 nF
1.0 nF	100 kHz	2	.99630 nF	1.0037 nF
10.0 nF	100 Hz	0	9.978 nF	10.022 nF
10.0 nF	1 kHz	1	9.978 nF	10.022 nF
10.0 nF	10 kHz	2	9.973 nF	10.027 nF
10.0 nF	100 kHz	2	9.963 nF	10.037 nF
100.0 nF	100 Hz	1	99.978 nF	100.22 nF
100.0 nF	1 kHz	2	99.978 nF	100.22 nF
100.0 nF	10 kHz	2	99.73 nF	100.27 nF
100.0 nF	100 kHz	3	99.63 nF	100.37 nF
1.0 µF	100 Hz	2	.99978 µF	1.0022 µF
1.0 µF	1 kHz	2	.99978 µF	1.0022 µF
1.0 µF	10 kHz	3	.9973 µF	1.0027 µF
10.0 µF	100 Hz	2	9.9978 µF	10.022 µF
10.0 µF	1 kHz	3	9.9978 µF	10.022 µF

Calibration Procedures

Introduction

Calibration of the Model Z9216 is composed of several parts: open and short circuit calibrations, standard resistor calibration, and amplitude calibration.

The open and short circuit calibrations (described in Volume 1 of this manual) are offset corrections to correct for any stray impedances of the test fixture. These Calibrations may be performed at any time and should be done whenever the fixture is changed.

The standard resistor calibration sets the accuracy of the Model Z9216, since it allows the LCR meter to determine the values of its internal standard resistors. The Standard Resistor Calibration need only be performed periodically to account for component aging and drift.

Amplitude calibration sets the amplitude of the AC test signal, and only needs to be done periodically. The amplitude calibration does not affect the Model Z9216's accuracy.

Calibration Enable

The Model Z9216 is shipped with amplitude calibration disabled. When calibration is disabled only the open and short circuit calibrations are allowed. The internal calibration enable jumper must be set to enable amplitude and resistor calibration. To set the jumper, remove the Model Z9216 top cover by removing its four retaining screws (this will break the calibration seal). In the rear center of the circuit board is a three-pin jumper labeled JP1001. Use the jumper to connect the center pin and the "cal" pin to enable calibration. Connecting the center pin and the "normal" pin will disable calibration.

Calbytes

The Model Z9216 calibration is controlled by calibration constants ("calbytes") that the firmware uses to adjust the impedance calculations. These calbytes are stored in the Model Z9216 RAM. Recalibration of the Model Z9216 involves determining new values of the calbytes and storing them in the RAM. The calbyte values that are determined at the time of the Model Z9216 manufacture are also stored in ROM and may be recalled at any time. The standard resistor calbytes are automatically determined by the standard resistor calibration subroutines. The amplitude calbytes must be manually determined.

The 95 amplitude calbytes, which are one-byte integers in the range of 0 to 255, are directly adjustable from the front panel and are organized as shown in Table 2-10. The 120 floating point frequency correction, reference resistor values, and open and short circuit calbyte values, whose organization is given in Table 2-11, are automatically determined by the Model Z9216's calibration subroutine. These calbytes cannot be directly changed from the front panel, but they may be changed via the computer interfaces.

Table 2-10 - Organization of Amplitude Calbytes to Amplitude and Frequency

Amplitude	Frequency				
	100 Hz	120 Hz	1 kHz	10 kHz	100 kHz
0.10 V	0	1	2	3	4
0.15 V	5	6	7	8	9
0.20 V	10	11	12	13	14
0.25 V	15	16	17	18	19
0.30 V	20	21	22	23	24
0.35 V	25	26	27	28	29
0.40 V	30	31	32	33	34
0.45 V	35	36	37	38	39
0.50 V	40	41	42	43	44
0.55 V	45	46	47	48	49
0.60 V	50	51	52	53	54
0.65 V	55	56	57	58	59
0.70 V	60	61	62	63	64
0.75 V	65	66	67	68	69
0.80 V	70	71	72	73	74
0.85 V	75	76	77	78	79
0.90 V	80	81	82	83	84
0.95 V	85	86	87	88	89
1.00V	90	91	92	93	94

Table 2-11 - Organization of Floating Point Calbytes

Calbyte Number	Name	Meaning
0	Frequency Correction	Deviation from nominal, in ppm
1–40	Reference Resistor Values	Impedance values organized in real and imaginary pairs
41–80	Open Circuit Values	Admittance values organized as real and imaginary pairs
81–120	Short Circuit Values	Impedance values organized in real and imaginary pairs

Necessary Equipment and Conditions

To perform the amplitude, frequency, or standard resistor calibration, the following equipment is needed:

- A time interval counter, with an accuracy of 1 ns or better.
- An AC/DC voltmeter, with 5 ½ -digit DC accuracy and true RMS AC measurements to 100 kHz.
- Standard resistors, with resistance known to 0.01% and Q accuracy known to 25 ppm. The resistor values needed are 95.300 kΩ (R0), 5.970 kΩ (R1), 374.0 Ω (R2), and 25.10 Ω (R4).
- A fixture-to-BNC adapter.

The conditions for calibration include a warm-up time of at least 30 minutes and an ambient temperature of 23°C ± 5°C (73°F ± 9°F).

Amplitude Calibration

This procedure calibrates the output amplitude at the different frequencies and output voltages. To adjust the calbytes, press the **CAL** key until the message "cl I" appears in the display, where I is an integer. The present value of that calbyte will appear in the right display. The ↑ and ↓ frequency keys step through the different amplitude calbytes. New values are entered using the numeric entry keys.

1. Connect the AC/DC voltmeter across the two sides of the fixture. A small piece of wire inserted in each side of the fixture is a convenient way to connect the DVM. Do not connect either end to ground. Set the meter to AC volts, autoranging. Set the Model Z9216 to its default conditions by pressing the keys, **RCL 0 ENTER**. Set the unit to constant voltage mode.
2. Measure the amplitude and frequency for amplitude calbyte 0 (0.10 V and 100 Hz). If the value is not within 2% of the nominal value, enter the new calbyte using the formula:

   $NewCalbyte = \frac{Vnom}{Vmeas} \times CurrentCalbyte$, rounded to the nearest integer
3. Verify that the amplitude is within 2% of the nominal value. See Table 2-12 below for the acceptable limits for each amplitude.
4. Repeat steps 2 and 3 for 120 Hz, 1 kHz, 10 kHz, and 100 kHz (Calbytes 1, 2, 3 and 4) at this amplitude (0.10 V). Note that, for each amplitude, the calbyte numbers are in order of ascending frequency.
5. Repeat steps 2 to 4 for each amplitude in the table. At each amplitude, repeat the measurement for each frequency, starting with 100 Hz and increasing to 100 Hz.

Table 2-12 - Amplitude Limits

Calbyte	Nominal Voltage	Limits
0-4	0.100	0.098-0.102
5-9	0.150	0.147-0.153
10-14	0.200	0.196-0.204
15-19	0.250	0.245-0.255
20-24	0.300	0.294-0.306
25-29	0.350	0.343-0.357
30-34	0.400	0.392-0.408
35-39	0.450	0.441-0.459
40-44	0.500	0.490-0.510
45-49	0.550	0.539-0.561
50-54	0.600	0.588-0.612
55-59	0.650	0.637-0.663
60-64	0.700	0.686-0.714
65-69	0.750	0.735-0.765
70-74	0.800	0.784-0.816
75-79	0.850	0.833-0.867
80-84	0.900	0.882-0.918
85-89	0.950	0.931-0.969
90-94	1.000	0.980-1.020

Frequency Calibration

This procedure measures the accuracy of the Model Z9216 clock. The exact clock frequency is used in calculating capacitance and inductance values. The clock correction factor is stored in parts per million (ppm).

1. Set the Model Z9216 to its default conditions by pressing the keys **RCL 0 ENTER**. Set the unit to constant voltage mode at 1 kHz, and remove any part from the fixture.
2. Install the BNC adapter to the fixture. Connect the IH lead to the frequency counter.
3. Determine the new calbyte by the formula, Calbyte = (frequency − 1000.000) × 1000.
4. To adjust the clock calbyte, press the **CAL** key until "Std CAL" appears on the display. Press **ENTER** once to get into this menu structure, and then press **CAL** until the message "df" appears on the left alphanumeric display and the current value on the right display. Enter the new value, in ppm using the entry keys. To exit the standard cal menu, press **CAL** until the "quit CAL" message appears, and then press **ENTER**.

Standard Resistor Calibration

This procedure determines the value of the internal standards for the different frequencies and ranges. The Model Z9216 does this by measuring a precisely known resistor and recomputing the values it uses when calculating the impedance of a part. These values are the primary accuracy standard of the instrument, so the exact value of the calibration resistor, both real and imaginary parts, must be known. In addition, the Model Z9216 and the calibration resistors must be placed in a temperature controlled room and allowed to stabilize at least 30 minutes before attempting calibrate.

The standard cal menu is entered as follows: Press the **CAL** key until "Std CAL" appears on the alphanumeric display. Press **ENTER** once to get into this menu structure. Next press **CAL** until the "rAngE" message appears on the left display. From here the desired range can be entered (using the **0** to **3** numeric keys and **ENTER**) and will appear on the right display.

After the range has been entered, pressing **CAL** will cycle through a series of menus. Pressing **ENTER** in any of these will either load that value or begin the action listed. Two different parameters must be set, "r Std" (standard resistor resistance value) and "q Std" (Q of the standard resistor). Resistance values are entered using the Ω, **k**Ω, and **M**Ω keys and Q is entered in ppm. Negative Q's denote capacitive resistors and positive Q's denote inductive ones. The different actions are "StArt CAL" (start cal), "Fctry CAL" (factory cal) and "quit CAL" (quit cal). These activities will, in order, begin calibration of the current range, recall the factory default values, or exit the cal menu.

1. Inspect the fixture contacts for dirt or waxy build up. If the fixture appears dirty, clean it. Remove any adapters or components from the fixture.
2. Perform open and short circuit calibration.
3. Plug the R0 calibration resistor into the fixture. Enter the cal menu as described above and enter range 0.

   - Press **CAL** until "r Std" (resistance standard) is displayed. Enter the resistance of R0.
   - Press **CAL** to display "q Std: (Q standard) and enter the Q of the standard in ppm.
   - Press **CAL** to display "StArt CAL" (start cal). Begin the calibration by pressing **ENTER**, making sure to keep hands and any other objects away from the fixture.

4. Repeat step 3 for the other three ranges (1, 2 and 3). When finished, exit the cal menu by pressing **CAL** until "quit CAL" is displayed and then press **ENTER**.
5. After calibration, verify that the calibration is accurate. Perform open and short circuit calibration. Insert the standards in the fixture and measure them at 1 kHz, series equivalent circuit. The R and Q readings should agree to within one least significant digit of the standard values.
6. Check the standards at different frequencies. Use the series equivalent for the two smaller resistors and the parallel equivalent for the two larger ones. R should remain relatively constant and Q should scale with frequency (i.e. Q at 10kHz is 10 × Q at 1 kHz). If any of the values are too far from the nominal values, recalibrate that range.
7. Before making measurements, run open and short circuit calibration with the fixture configuration to be used.

Chapter
3

Remote Control of the LCR Meter

Remote Programming Reference

The Model Z9216 LCR meter may be controlled and programmed remotely using either an RS-232 or the optional GPIB (IEEE488) interface. Any computer supporting either of these interfaces may be used with the Model Z9216. Both interfaces are simultaneously active and are accessed via the connectors on the rear panel. The Model Z9216 responds to commands from either interface and returns answers to the interface from which the command came. All front and rear panel features (except power) may be controlled.

Using the Interfaces

RS232 Interface

The RS232 interface specifies how to transfer data between a DTE, (data terminal equipment), device such as a computer, and a DCE, (data communications equipment), device such as a modem. The interface includes two signal lines that can be used for half-duplex (one-way) or full duplex (simultaneous two-way) operation. Additional lines are used for controlling the flow of the data in the sense that data cannot be transferred unless the appropriate flow control line is first asserted (changed from 0 to 1).

The RS232 Interface Standard

The RS232 interface standard specifies a 25-pin connector as the standard interface in data communications networks—a 25-pin D-SUB male connector at the DTE (data terminal equipment) and a 25-pin D-SUB female connector at the DCE (data communications equipment)—with the pins designated as shown in Table 3-1. The most common RS232 signals are the following:

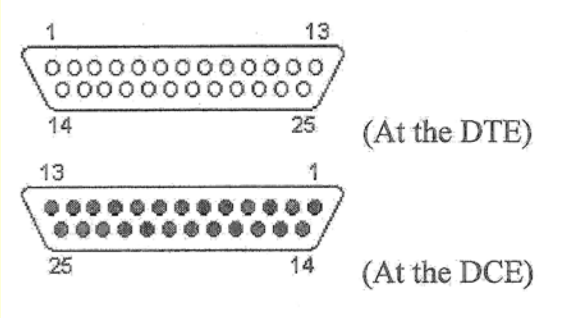
- Request to Send (RTS) and Clear to Send (CTS): The RTS signal line is asserted by the computer to inform the modem that it wants to transmit data. If the modem decides that it is read to receive data, it will assert the CTS line. Typically, once the computer asserts RTS, it will wait for the modem to assert CTS before transmitting data.

- Data Terminal Ready (DTR) and Data Set Ready (DSR): This line is asserted by the computer to inform the modem that it is ready to receive data. In response, the modem will assert DSR to indicate that it is turned on.

- Carrier Detect (CD): This control line is asserted by the modem, informing the computer that it has established a physical connection to another modem and is ready to transfer data.

In the application of the RS232 interface to the remote control of the LCR Meter, the meter plays the role of a modem, and the flow of data is primarily measurements transmitted from the meter to the computer.

Table 3-1 - RS-232 Signals and Pin Assignments



Pin	Signal	Direction	Description
1	GND	—	Protective Shield Ground
2	TXD	→	Transmit data
3	RXD	←	Receive Data
4	RTS	→	Request to Send
5	CTS	←	Clear to Send
6	DSR	←	Data Set Ready
7	GND	—	System Ground
8	CD	←	Carrier Detect
9			RESERVED
10			RESERVED
11	STF	→	Select Transmit Channel
12	S.CD	←	Secondary Carrier Detect
13	S.CTS	←	Secondary Clear to Send
14	S.TXD	→	Secondary Transmit Data
15	TCK	←	Transmission Signal Element Timing
16	S. RXC	←	Secondary Receive Data
17	RCK	←	Receiver Signal Element Timing
18	LL	→	Local Loop Control
19	S.RTS	→	Secondary Request to Send
20	DTR	→	Data Terminal Ready
21	RL	→	Remote Loop Control
22	RI	←	Ring Indicator
23	DSR	→	Data Signal Rate Selector
24	XCK	→	Transmit Signal Element Timing
25	TI	←	Test Indicator

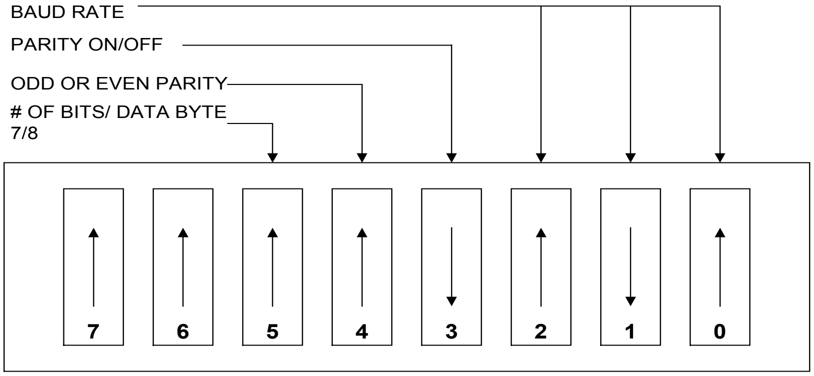
The Model Z9216 is configured as a DCE (transmit on pin 2, receive on pin 3) and supports the CTS/DTR hardware handshaking discussed above. The CTS signal (pin 5) is an output of the meter indicating that the Model Z9216 is ready, while the DTR signal (pin 20) is an input to the meter that is used to control the Model Z9216 transmissions. If desired, the handshake pins may be ignored and a simple three-wire interface (pins 2, 3 and 7) may be used.

Before communicating with the Model Z9216, the RS232 characteristics must be set. As shown in Table 3-2, the RS232 interface is configured using the rear panel switches SW1-1 to SW1-7. The last three switches set the baud rate to 300, 600, 1200, 2400, 4800, or 9600 baud. Parity may be enabled or disabled, and set to even or odd, and, the number of bits in a data byte may be set to 7 or 8.

Note: the Model Z9216 must be set to eight data bits if binary data output formats are used.

Table 3-2 - SW1 Settings for the RS-232 Parameters

BAUD RATE			
SW1-0	SW1-1	SW1-2	Baud Rate
ON	ON	ON	300 Hz
OFF	ON	ON	600 Hz
ON	OFF	ON	1200 Hz
OFF	OFF	ON	2400 Hz
ON	ON	OFF	4800 Hz
OFF	ON	OFF	9600 Hz
ON	OFF	OFF	19.2 kHz
FORMAT			
SW1-3	OFF	Parity On	
	ON	Parity Off	
SW1-4	OFF	Even Parity	
	ON	Odd Parity	
SW1-5	OFF	8 Data Bits	
	ON	7 Data Bits	



RS232 SWITCH CONFIGURATION ON THE 2600/2610 REAR PANEL
THIS SETUP SHOWS SETTING FOR 9600 BAUD, NO PARITY, AND 8 DATA BITS

Optional GPIB (IEEE 488) Interface (Model Z9216-4 Only)

The IEEE-488 Interface Standard

The General Purpose Interface Bus (GPIB), also known as the IEEE-488 interface, is an 8-bit parallel bus common on test equipment. The IEEE-488 standard was proposed by Hewlett-Packard in the late 1970s and has undergone several revisions. HP documentation (including data sheets and manuals) calls it HP-IB, or Hewlett-Packard Interface Bus. It allows up to 15 intelligent devices to share a single bus, with the slowest device participating in the control and data transfer handshakes to drive the speed of the transaction. The maximum data rate is about one megabit per second.

In June 1987, the IEEE approved a new standard for programmable instruments called ANSI/IEEE Std. 488.2-1987 Codes, Formats, Protocols, and Common Commands. It is backward compatible with the IEEE Standard Digital Interface for Programmable Instrumentation, ANSI/IEEE 488-1978 (now 488.1). HP-IB is Hewlett-Packard's implementation of IEEE 488.1. The Standard Commands for Programmable Instruments (SCPI) portion of IEEE 488.2 uses the command structures defined in IEEE 488.2 to create a single, comprehensive programming command set for use with any SCPI instrument.

GPIB devices communicate with other GPIB devices by sending device-dependent messages and interface messages on the bus. The devices can be Talkers, Listeners, or Controllers. A Talker sends data messages to one or more Listeners, which receive the data. The Controller manages the flow of information on the GPIB by sending commands to all devices. A digital voltmeter, for example, is a Talker and also a Listener.

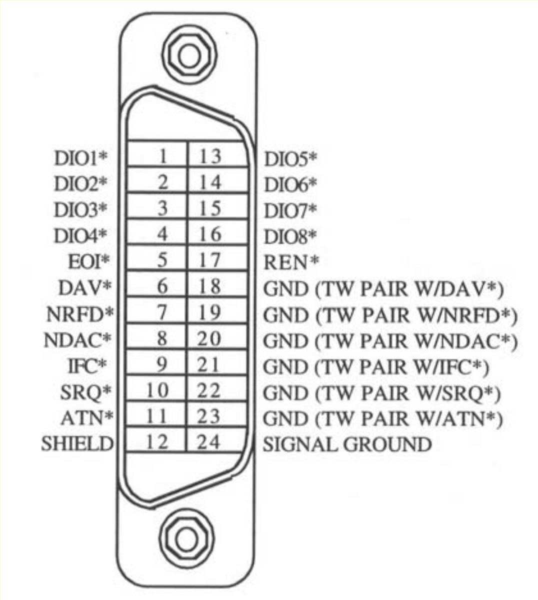
The GPIB is similar to a computer bus, but instead of connecting different PC cards on a motherboard, the GPIB connects them by standard cables. The role of the GPIB Controller is comparable to that of a computer's CPU or, more aptly, that of switching center of a telephone system. The switching center (Controller) monitors the communications network (GPIB). When the Controller notices that a party (device) wants to make a call (send a data message), it connects the caller (Talker) to the receiver (Listener). The Controller usually addresses (enables) a Talker and a Listener before the data message can be sent.

Some GPIB configurations do not require a Controller, such as when a device that is always a Talker is connected to one or more listen-only devices. A Controller is necessary when the active Talker or Listener must be changed. The Controller function is usually handled by a computer, which with the appropriate software and hardware can perform the roles of Controller and Talker/Listener.

As detailed in Table 3-3, the GPIB interface system utilizes a 24-pin ribbon-type connector, with 16 signal lines and eight ground-return or shield-drain lines. The 16 signal lines within the passive interconnecting HP-IB (IEEE-488) cable are grouped into three clusters according to their functions:

- Data Bus (eight lines): DI01 to DI08, data lines that carry either data or command messages. All commands and most data use the 7-bit ASCII code set, the eighth bit, DI08, being used for parity when parity is used.
- Handshaking or Data Byte Transfer Control Bus (three lines): NRFD (not ready for data), NDAC (not data accepted), and DAV (data valid). The use of these lines, together with the settling time properties of the line and its termination, determine the speed of the data transfer.
- General Interface Management Bus (five lines): ATN (attention), IFC (interface clear), REN (remote enable), SRQ (service request), and EOI (end or identify).

Table 3-3 - GPIB (IEEE-488) Connector and Pin Assignments



Pin	Signal	Description
1 to 4	DI01 to DI04	Data lines.
5	EOI	End or Identify. The Talker uses the EOI to mark the end of a message string, while the Active Controller uses it to tell devices to identify their responses in a parallel poll.
6	DAV	Data Invalid. Indicates the data lines are stable and can be sampled.
7	NRFD	Not ready for data. Used by receiving devices.
8	NDAC	Not data accepted. Used to signal when a device accepts data.
9	IFC	Interface clear. Used by the Controller to initialize the bus.
10	SRQ	Service request. Used by a device to request service from Controller.
11	ATN	Attention. TRUE during Controller use of the data lines.
12	Shield	
13 to 16	DI05 to DI08	Data lines.
17	REN	Remote enable. Used by Controller to enable selected devices.
18	GND (w. DAV)	Return lines in twisted pairs with the signal lines indicated
19	GND (w. NRFD)	
20	GND (w. DAC)	
21	GND (w. IFC)	
22	GND (w. SRQ)	
23	GND (w. ATN)	
24	Signal Ground	Ground return line for the data.

Setting Up to Use the IEEE-488 Interface

The Model Z9216 supports the IEEE-488.1 (1978) interface standard. It also supports the required common commands of the IEEE-488.2 (1987) standard.

Before attempting to communicate with the Model Z9216 over the GPIB interface, the Model Z9216 device address must be set. The address is set by the rear panel dip switch, SW2. The address may be set between 0 and 30 by setting the binary value of the address on switches A0 to A4. Each switch may have the value 0 (down) or 1 (up). The address is set by the formula:

Address = A0 +2*A1+4*A2+8*A3+16*A4.

Connect IEEE-488 cable (Dual Centronics 24-pin connector) to the IEEE-488 (GPIB) and secure the connector by tightening the screw.

Optional Handler Interface

Introduction

The optional handler interface for the Model Z9216 allows the unit to be operated with external hardware to measure and physically sort components. Data lines for ten sorting bins are provided, as well as control lines (-START, -BUSY, -BDA) to coordinate measurements. See Chapter 4 for information on bin setup procedures and options.

A timing diagram for the handler interface is shown in Figure 3-1. In the states labeled (a) in the figure, the Model Z9216 is waiting for a trigger to start measuring. Previous bin data, if any, is still available on the data outputs.

In the states labeled (b) in the figure, a negative going pulse on the –START line triggers a measurement. The –BUSY line goes low and stay low until the measurement is completed.

In the states labeled (c) in the figure, after taking the measurement the Model Z9216 determines the proper bin to place the component. During this time, the –BDA (bin data available) line is activated to prevent reading invalid data. After the proper bin location has been selected, the –BDA line will go high, and the appropriate bin line will be pulled low (only a single bin line will be low at any time). The external handler can now remove the component, place it in the specified location, and insert a new one into the fixture. The Model Z9216 returns to the states labeled (a).

Note: Some handlers can be programmed to remove the component under test to the sorting area as soon as the –BUSY line goes high.

Mechanical Description

The handler interface is part of the Option 01 GPIB/Handler board and is accessed via a 25-pin connector on the rear panel of the Model Z9216. A DB25 female connector, metal housing, and sheath are provided to simplify construction of a cable to the external handler. The connector pin out for the handler is shown in Table 3-4.

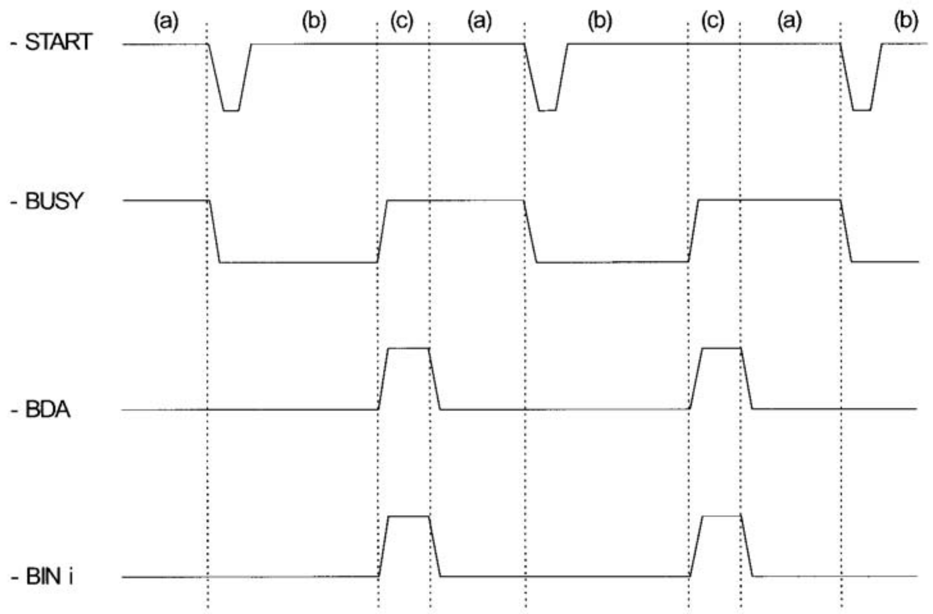


Figure 3-1 - Handler Interface Timing Diagram.

Table 3-4- Pinout for Handler Interface Connector

Pin	Signal	Pin	Signal
1		14	
2		15	
3	-START	16	
4		17	
5		18	GND
6	GND	19	+5 supply
7	+5 supply	20	-BDA
8	-BUSY	21	Bin 9
9	Bin 8	22	Bin 7
10	Bin 6	23	Bin 5
11	Bin 4	24	Bin 3
12	Bin 2	25	Bin 1
13	Bin 0		

The trigger input (-START) line is active low and requires a pulse width of at least 50 ns to activate the edge-triggered circuitry, which uses 1N4148 diodes to protect against voltages exceeding TTL levels. Outputs are provided by 7406 inverting buffers, which have open-collector outputs and therefore need pull-up resistors on the handler for proper operation.

NOTE: The maximum high-level output voltage is 30 V, and the maximum low-level output current is 40 mA. For example, when connecting the output to a 5 V supply at the handler, the pull-up resistors should be no smaller than 5 V/40 mA = 125 ohms. Flyback diodes should be added if the outputs are used to drive relay coils, but such a direct connection is not recommended. Ideally, opto-isolators should be used on all data lines to prevent noise from the handler from interfering with measurements.

Using Commands

Communications with the Model Z9216 use ASCII characters. Commands may be in either UPPER or lower case and may contain any number of embedded space characters. A command to the Model Z9216 consists of a four-character command mnemonic, arguments if necessary, and a command termination. The terminator may be either a carriage return <CR> or line feed <LF> on RS232, or a line feed <LF> or EOI on GPIB. No command processing occurs until the meter receives a command termination. All commands function identically on GPIB and RS232. Commands may require one or more parameters. Multiple parameters are separated by commas, ",".

Multiple commands may be sent on one command line by separating them by semicolons ";". The difference between sending several commands on the same line and sending several independent commands is that when a command line is parsed and executed the entire line is executed before any other device action proceeds.

There is no need to wait between commands. The Model Z9216 has a 256-character input buffer and processes commands in the order received. If the buffer fills up, the Model Z9216 will hold off handshaking on the GPIB and attempt to hold off handshaking on RS232. If the buffer overflows the buffer will be cleared and an error reported. The GPIB output buffer may be cleared by using the Device Clear universal command.

The present value of a particular parameter may be determined by querying the Model Z9216 for its value. A query is formed by appending a question mark "?" to the command mnemonic and omitting the desired parameter from the command. If multiple queries are sent on one command line (separated by semicolons, of course) the answers will be returned in a single response line with the individual responses separated by semicolons. The default response delimiter that the Model Z9216 sends with any answer to a query is carriage return-line feed <CR> <LF> on RS232 and line feed plus EOI on GPIB, except for binary answers, which are delimited by a line feed signal <LF> on both interfaces. All commands return integer results except as noted in individual command descriptions. Example command formats are given in Table 3-5.

Table 3-5 - Examples of Command Formats

<LF>	Sets the drive frequency to 100 Hz (one-parameter command)
FREQ ? <LF>	Queries the drive frequency (query of one-parameter command
BLIM 0, 3, 100 <LF>	Sets the upper limit of bin 3 to 1000 Ω (three-parameter command
BLIM ? 0, 3 <LF>	Queries the upper limit of bin 3 (query of a three-parameter command)
*IDN ? <LF>	Queries the device identification (query with no parameters)
*TRG <LF>	Triggers a measurement (command with no parameters)
FREQ 1; FREQ ? <LF>	Sets frequency to 120 Hz, then queries the frequency.

List of Commands

VARIABLES	i, j Integers x Real Number
MEASUREMENT SETUP	
$STL(?) {i}	Set (query) settling time to between i = 2 and i = 99 milliseconds.
AVGM(?) {i}	Set (query) averaging on (i = 1) or off (i = 0)
BIAS(?) {i}	Set (query) DC bias to internal (i = 1), external (i = 2), or off (i = 0)
CAL? {i}	Enable Calibration Mode: short circuit (i = 0) open circuit (i = 1) & Standard Resistance (i = 2). *See Below for more details
CIRC(?) {i}	Set (query) equivalent circuit to series (i = 0) or parallel (i = 1)
CONV(?) {i}	Set (query) constant voltage mode on (i = 1) or off (i = 0)
FREQ(?) {i}	Set (query) drive frequency to 100 Hz(0), 120 Hz(1), 1 kHz(2) or 100 kHz(4)
MMOD(?) {i}	Set (query) measurement mode to continuous (i = 0) or triggered (i = 1)
NAVG(?) {i}	Set (query) number of measurements to be averaged from i = 2 to i = 10
PMOD(?) {i}	Set (query) parameter mode to Auto(0), R+Q(1), L+Q(2), C+D(3), or C+R(4)
RATE(?) {i}	Set (query) measurement rate to Fast(0), Medium(1) or Slow(2)
RNGE(?) {i}	Set (query) meas. range to 100 kΩ(0), 6.4 kΩ (1), 400 Ω, (2) or 25 Ω (3)
RNGH(?) {i}	Set (query) range hold to enabled (i = 1) or disabled (i = 0)
VOLT(?) {x}	Set (query) drive voltage to $0.1\ \mathrm{V} \le x < 1.00\ \mathrm{V}$ with 0.05 V resolution.
MEASUREMENT CONTROL	
PREL(?) {x}	Set (query) nominal parameter value for deviation and %deviation to x (Ω,F,H)
STRT	Starts a measurement.
STOP	Stops the current measurement.
*TRG	Same as STRT.
MEASUREMENT OUTCOME	
OUTF(?) {i}	Set (query) the output format to verbose (0) or concise (1) ASCII, or verbose (2) or concise (3) binary.
XALL?	Returns major and minor parameters plus bin number.
XBIN?	Returns bin number of current measurement.
XDLT?	Returns deviation between major parameter and nominal value.
XMAJ?	Returns value of the major parameter.
XM1N?	Returns value of the minor parameter.
XPCT?	Returns percent deviation between major parameter and nominal value.

BINNING	
BCL **BING(?) {i}** **BLIM(?) i j {x}** **BNOM(?) i {x}**	Clears nominal values and limits for all bins. All bins are closed. Set (query) binning to enabled (i = 1) or disabled (i = 0). Set (query) upper (i = 0) or lower (i = 1) limit of bin j (0-7) to x%. Set nominal value of bin i to x
SETUP CONTROL	
***IDN?** ***OPC(?)** ***RCL {i}** ***RST** ***SAV{i}** ***WAI**	Returns the Model Z9216 identification string. Set bit in Standard Event Status byte when measurement is complete. Recall setting i. Reset unit to default configuration. Save current setup as setting i. Wait until all measurements are completed before proceeding.
STATUS	
***CLS** ***ESE(?) {i}** ***ESR? {i}** ***PSC(?) {i}** ***SRE(?) {i}** ***STB? {i}** **SENA(?) {i}** **STAT? {i}**	Clear all status registers. Set (query) the Standard Event Status Byte Enable register to value i (0-255). Query Standard Status byte. If i is included, only bit i is queried. Set (query) power-on status clear bit to clear (i = 1) or maintain (i = 0) status values. Set (query) the Serial Poll Enable register to value i (0-255). Query Serial Poll status byte. If i is included, only bit i is queried. Set (query) LCR Status Enable register to value i (0-255). Query LCR Status byte. If i is included, only bit i is queried.

Performing a Remote Calibration and Hardware Test via RS232 or GPIB

Many automated setups require frequent open and short circuit calibrations. The Model Z9216 allows the user to perform open and short circuit calibrations remotely so that no external interference is required. Thus allowing the manufacturing process to continue uninterrupted.

The open and short circuit calibration may be performed by initiating the "*CAL {i}" command. The following tables summarize the variations and return values for the CAL command. Warning: The Standard Resistance Calibration should only be performed by qualified personnel.

Variations of the CAL Command

Value for {i}	Calibration Type
0	Short Circuit
1	Open Circuit
2	Standard Resistance

Return Values for the CAL Query

Result Value	Remark
0	OK - The Calibration was successfully accomplished
1	Measurement Error
2	Short Circuit Error – Impedance too High
3	Open Circuit Error – Impedance too Low
4	Standard Resistance Calibration Error. The Value of Calibration is out of Range

Status Displays and Error Messages

Adjacent to the right alphanumeric displays, the Model Z9216 has three front panel status LEDs that provide positive indication of commands and communications to help verify operations during the development of control programs. The ACT LED flashes whenever a character is received or sent over either interface. The ERR LED flashes when an error has been detected, such as an illegal command, or parameter out of range. The REM LED is lit whenever the Model Z9216 is in a remote state (front panel locked out).

The Model Z9216 reports two types of errors that may occur during command execution: command errors and execution errors. Command errors are errors in the command syntax. For example, unrecognized commands, illegal queries, lack of terminators, and non-numeric arguments are examples of command errors. Execution errors are errors that occur during the execution of syntactically correct commands. For example, out of range parameters and commands that are illegal for a particular mode of operation are classified as execution errors.

The NO COMMAND bit is a bit in the serial poll register that indicates that there no commands waiting to be executed in the input queue. This bit is reset when a complete command is received in the input queue and is set when all of the commands in the queue have been executed. This bit is useful in determining when all of the commands sent to the Model Z9216 have been executed. This is convenient because some commands, such as taking a measurement, or auto calibration, take a long time to execute and there ia no other way of determining when they are done. The NO COMMAND bit may be read while commands are being executed by doing a GPIB serial poll. There is no way to read this bit over RS232. Note that using the *STB? query to read this bit will always return the value 0 because it will always return an answer while a command is executing - the *STB? command itself.

Definitions of Status Bytes

Serial Polling

Bit	Name	Usage
0	Ready	The Model Z9216 is ready to perform a measurement
1	Not used	
2	Not used	
3	LCR	An unmasked bit in the LCR status register has been set.
4	MAV	The GPIB output queue is non-empty
5	ESB	An unmasked bit in the standard status byte has been set.
6	RQS / MSS	SRQ (Service Request) bit.
7	No command	There are no unexecuted commands in the input queue.

Standard Event

Bit	Name	Usage
0	OPC	Set by the OPC command when all measurements are complete
1	Not used	
2	Query Error	Set on output queue overflow (too many responses waiting to be transmitted.)
3	Not used	
4	Execution err	Set by an out of range parameter, or non-completion of some command due a condition such as an incorrect operating mode.
5	Command err	Set by a command syntax error, or unrecognized command
6	URQ	Set by any key press
7	PON	Set by power on

Measurement

Bit	Name	Usage
0	Math Error	Set on a floating point error.
1	A/D Error	Set when an A/D conversion fails.
2	Overload	Set when the gain stage is overloaded.
3	Under range	Set when a measurement is below the nominal range of values for the present range
4	Over range	Set when a measurement is below the nominal range of values for the present range
5	Out of Range	Set when the unit is unable to make a valid measurement on the current range.
6	Not used	
7	mem err	The stored settings were invalid on power up.

Chapter 4

Binning

Using the LCR Meter to Sort Components

The Model Z9216 has built in features to aid in component sorting, which is useful for production testing, incoming inspection, device matching, or tests in which multiple components of similar value must be measured. The binning feature simplifies parts sorting by eliminating the need to read the major and minor parameters and then deciding what to do with the part. The STO and RCL keys allow up to nine binning configurations to be entered and recalled. The configuration can also be programmed over one of the computer interfaces. The Model Z9216 can sort components into as many as ten separate bins-eight pass bins, a minor parameter failure bin, and a general failure bin. Binning operations can either be performed using the keys in the BINS group of keys, over the standard RS232 computer interface, or over the optional GPIB or Handler interface.

Binning Options

Three different types of binning schemes are supported by the Model Z9216: Pass/Fail, Overlapping, and Sequential. Pass/Fail has only two bins; good parts and all others. Overlapping (nested) bins have one nominal value and are sorted in progressively larger bins (for example, ±1%, ±2%, ±3%, etc.). Sequential bins can have different nominal values, each separated by a percentage (for example, 0.9*nom, 0.95*nom, 1.0*nom, 1.05*nom, with 5% limits). Alternatively, sequential bins can be set up with a single nominal value and asymmetrical limits (for example, –3% to –1%, –1% to 1%, to 3%). Bin limits are pairs and can be symmetrical (for example, ±2%) or asymmetrical (for example, –5% to –1%).

Binning Examples

Nested Bins

Suppose that a batch of 100 Ω resistors are to be sorted according to tolerance. The bins can be set up for this purpose as follows:

Bin 0:	99 Ω < R < 101 Ω	(±1%)
Bin 1:	98 Ω < R < 99 Ω, 101 Ω < R < 102 Ω	(±2%)
Bin 2:	97 Ω < R < 98 Ω, 102 Ω < R < 103 Ω	(±3%)
Bin 3:	96 Ω < R < 97 Ω, 103 Ω < R < 104 Ω	(±4%)
Bin 8:	QDR (quality deficiency report) failure (if Q is too high)	
Bin 9:	General failure bin (parts not falling into any other bin)	

Figure 4-1 illustrates\ this example of nested bins.

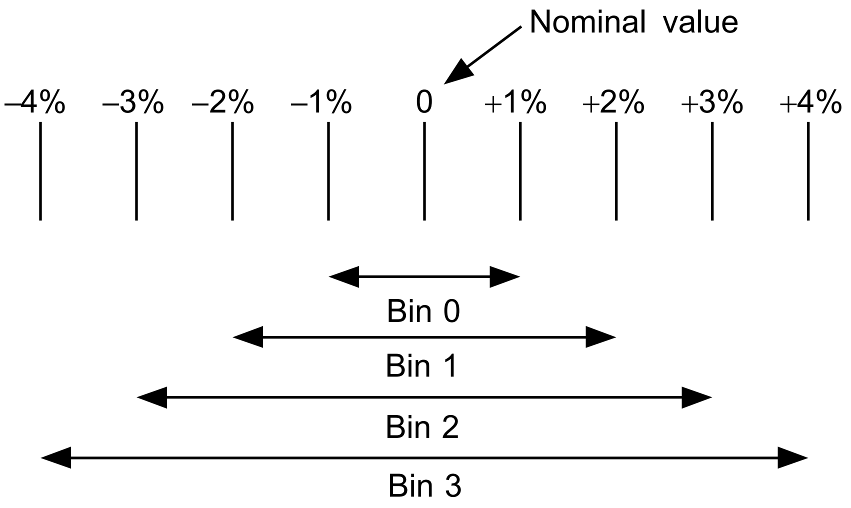


Figure 4-1 - Example of Nested Bins

Sequential Bins With Different Nominal Values

Suppose that the batch of nominally 100 Ω resistors is to be sorted according to actual value instead of according to tolerance, as in the previous example. Then the bins can be set up to have different nominal values, with each bin width expressed as a percentage of the nominal value:

Bin 0:	98 Ω ± 1%
Bin 1:	100 Ω ± 1%
Bin 2:	102 Ω ± 1%
Bin 3:	104 Ω ± 1%
Bin 4:	106 Ω ± 1%
Bin 8:	QDR failure (if Q is too high)
Bin 9:	General failure bin (parts not falling into any other bin)

Figure 4-2 illustrates this example of sequential bins with different nominal values.

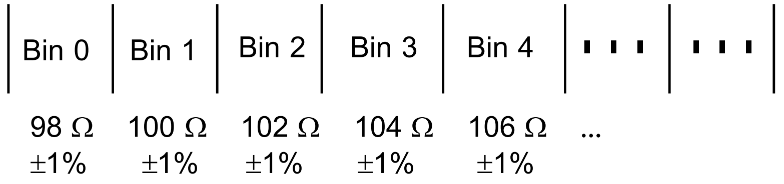


Figure 4-2 - Example of Sequential Bins With Different Nominal Values

Sequential Bins With a Single Nominal Value

Suppose that the batch of nominally 100 Ω resistors is to be sorted according to tolerance, as in the first example, but with the ability to distinguish between the low and high values. Then the bins can be set up to have the same nominal values, with each bin having asymmetric limits that are expressed as a percentage of the nominal value:

Bin 0:	95 Ω < R < 97 Ω	(–5%, –3%)
Bin 1:	97 Ω < R < 99 Ω	(–3%, –1%)
Bin 2:	99 Ω < R < 101 Ω	(–1%, +1%)
Bin 3:	101 Ω < R < 103 Ω	(+1%, +3%)
Bin 4:	103 Ω < R < 105 Ω	(+3%, +5%)
Bin 8:	QDR failure (if Q is too high)	
Bin 9:	General failure bin (parts not falling into any other bin)	

Figure 4-3 illustrates this example of sequential bins with different nominal values.

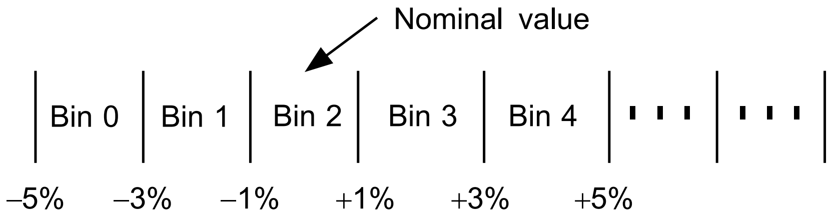


Figure 4-3 - Example of Sequential Bins With a Single Nominal Value

General Procedures

Binning data can be entered manually using the **BIN#**, **NOM**, and **LIM** keys, or over the RS232 or optional GPIB interface.

A bin is defined by a bin number, with a nominal value and upper and lower limits (in per cent). If a nominal value is not entered for a bin, it will take the nominal value of the next lower bin. Bin 0 is the exception; if bin 0 does not have a nominal value and limits, all parts will fail. Parts that fall into more than one bin are assigned to the lower numbered bin. Thus, the tightest tolerance should be assigned to the lowest bin number. Any parts that fall into gaps between bins are assigned to the general failure bin (Bin 9). If only one limit of a pair is entered, the limits will be assumed to be a a symmetric pair (± X%, where "X" is the entered limit value). Unused bins should be closed (assigned 0% limits). After bin clear or **RCL 0**, all bins are closed.

Parts that would fall into both the general failure bin (Bin 9) and the QDR failure bin (Bin 8) are assigned to the QDR fail bin only. The QDR limits are maximums depending on which parameter is being measured. If a Q value is negative, (for a resistor) the absolute value should be entered, and the meter performs a comparison between the absolute value of the QDR reading and the QDR limit. There are no limits for the QDR bin, only a nominal value. To disable the QDR comparison, set the nominal value to its extreme value, as listed in Table 4-1.

Table 4-1 - QDR Limits and Extreme Values

Measurement Mode	QDR Limit	Extreme Value
R + Q	Q maximum	9999.9
L + Q	Q minimum	0
C + D	D maximum	9999.9
C + R series	R maximum	99999
C + R parallel	R minimum	0

Setting Up the Bins

Procedures

Initial Setup

To enter binning information the unit cannot be in the AUTO parameter mode. Make certain that the unit is set to the correct measurement mode (R+Q, L+Q, C+D or C+R). Press the **BIN#** key, which will bring up the bin entry display and put the unit in the entry mode. If any previous binning information needs to be cleared, press the **BIN#** key until the “bin CLEAR” message appears.

Press the **ENTER** key to clear all bin data and display “CLEAR donE”.

To enter new bin data or to edit old bin data (if it was not previously cleared), press the **BIN#** key until displays “bin x”. Enter the desired bin number (press a numeric key, **0** through **8**, then **ENTER**). The bin number will appear on the right alphanumeric display. This is the bin for which subsequent nominal and limit values will be entered.

Nominal Values for Pass Bins 0 to 7

To enter the nominal value, press the **NOM** key. The NOM LED below the alphanumeric display will turn on. The display will show the present nominal value, or “----“ if the bin was previously shown closed in the left display. If a nominal value is needed for this bin, enter the desired nominal value with the numeric keys and the unit entry keys. The new nominal value, including units, will be displayed. Note that a nominal value does not have to be entered for each bin. If a bin does not have a nominal value, it will use the one from the bin below it.

Limits for Pass Bins 0 to 7

To enter the limits, press the **LIM** key. The display will show the present upper limit value, or “----“ if no limit was given previously. The +LIM LED below the display will turn on. Enter the limit value in percent using the numeric keys and the **ENTER** key. If it is necessary to enter a non-symmetrical limit pair, press the **LIM** key a second time to display the present lower limit value. The -LIM LED will turn on. Enter the lower limit in the same fashion as the upper one. For symmetric limits, enter only the upper value; the lower limit will be the negative of the upper limit. If no limits are entered for a bin, that bin will remain closed, even if it has a nominal value.

Values for Fail Bins 8 and 9

To set the QDR limit value, select Bin 8 (using the keys **BIN# 8 ENTER**) and press the **NOM** key. This action will generate a display of the present QDR limit, or "----", in the right alphanumeric display and turn on the NOM LED. Input the value with the numeric keys and press the **ENTER** key. Resistors for the C+R mode are entered in Ω (the allowable range of resistance values is only 0 to 9999 Ω, so no kΩ or MΩ key is needed). There are no limits for the QDR bin.

Bin 9, the general failure bin, cannot be set. Parts that do not fall into any other bin are assigned to this bin.

Enable Binning

To enable or disable binning, press the **BIN#** key until the "Sort Off" or "Sort On" message appears. Pressing the **ENTER** key from this display toggles binning (sorting) on and off. When binning is enabled, the BINNING LED is on, the BINS display is active, and the handler interface (if installed) is active. The handler interface is active whenever binning is enabled, whether or not the BINS display is on. See the Handler section for more information on the Handler interface.

Using a Worksheet and Reusing Setups

Before entering binning information, it is usually better to write down the desired binning setup since it is a fairly complicated procedure. See the binning worksheet below in Table 4-2.

Also, be sure to save setups that are used often. Certain setups can be edited, for example, one percent resistors using the same nominal value—a different value of resistance can be sorted by simply changing the nominal value, if the only nominal value entered was for Bin 0. For this reason, it is often better to enter sequential binning data with a single nominal value and different percentage limits, instead of with different nominal values. It is advisable to check the nominal values and limits before making measurements, to be certain that they have not been modified. The binning setup can be viewed in the same manner as it was entered; just do not press the **ENTER** key unless a value needs to be changed.

Table 4-2 - Binning Worksheet

	Date:		
	Nominal Value of Component:		
	Tolerance to be sorted to:		
	Entered by:		
	Type of binning:	Pass/Fail Nested Sequential	
Bin #	Nom	+lim	-lim
0			
1			
2			
3			
4			
5			
6			
7			
8		-----	------
9	-----	-----	-----

Summary of Binning Setups

Pass/Fail Setup

Enter the nominal value and limits for Bin 0. Enter the QDR fail value for Bin 8. Make sure no other bins are open (set their limits to zero). Parts that pass fall into Bin 0; and all other parts fall into Bin 8 or Bin 9.

Nested or Overlapping Bins

Enter the nominal value and limits for Bin 0. For subsequent bins, enter only the limits, making sure the tighter tolerance parts use the lower bins. If the limits are symmetrical, only enter the upper limit. Enter the QDR limit for Bin 8. Make sure all other bins are closed. Parts that pass fall into one of the pass bins. Parts that fail the QDR test fall in Bin 8 and parts that fall into no other bin fall into Bin 9.

Sequential Bins

For sequential bins with a single nominal value, follow the same procedure as for nested bins mentioned above.

For sequential bins with multiple nominal values, enter the nominal value and limits for each open bin. If the limits are symmetrical, only enter the upper limit. Enter the QDR fail value for Bin 8. Make sure that unused bins are closed (limits set to zero) and there are no unwanted gaps between bins.

Parts that pass fall into one of the pass bins. Parts that fail the QDR test fall in Bin 8 and parts that fall into no other bin fall into Bin 9.

Chapter
5

Troubleshooting

General Problems

Nothing Happens at Turn-on

Make sure that the power entry module on the rear panel is set for the AC line voltage for your region, that the correct fuse is installed, and that the line cord is inserted all the way into the power entry module. The selected line voltage may be seen through the clear window, just below the fuse.

When the unit is plugged in and turned "ON", the unit's program version number will be briefly displayed. Then the self-tests should execute.

Reset Procedure

If the unit displays no sensible message, the "cold boot" procedure may fix the problem. To reset the instrument, turn the unit off. Then, while holding the backspace key ([←]), turn the unit "ON". This procedure initializes the RAM and recalls the factory calibration and default values. The default parameter values and instrument settings are listed in Volume 1 of this manual.

Internal Fuse Check

If the unit powers on correctly but makes unstable or wildly inaccurate readings, the internal fuse may be blown. This can also cause the unit to fail the self-test (Out Err3). To change this fuse, the top of the unit must be removed. To do this, first turn off and unplug the unit. Next remove the four screws located on the bottom at the comers of the unit. Place the unit right side up on its feet and gently slide the plastic top off the metal base.

It is necessary to slide the top gradually off the fixture and the back panel, since it fits tightly over these. When the top is removed, stand it on its left side near the unit to avoid damaging the front panel cables. The internal fuse is located near the fixture, on the right hand side of the unit. Remove the old fuse and inspect it for damage. If it is damaged, replace it with a 250V, F250mA fuse. Replace the top, taking care to align it over the fixture and rear panel. Finally, replace the four screws and verify that this fixed the unit.

External Bias Fuse Check

If the unit makes unstable or wildly inaccurate reading when an external bias is applied, the external bias fuse may be blown. To change it, power off and unplug the unit. Use a screwdriver to remove the fuse holder and the fuse from the rear panel. Check the fuse with an Ohmmeter, if it is damaged, replace it with a 250V, F250mA fuse. Replace the fuse holder and fuse and verify that the unit operates correctly.

Error Messages

The following lists explain all of the error messages that the Model Z9216 can generate. The messages are divided into operational errors (errors in using the instrument), self-test errors, and calibration errors. The messages are listed alphabetically.

Operational Errors

These error messages may appear during normal front-panel operation and generally are warnings for incorrect operation.

Message	Meaning
Bias For C	The Model Z9216 DC bias function may only be used for capacitance measurements. Set the parameter mode to either C+D or C+R to use DC bias.
Cony Error	An A/D conversion that is either too short or too long can produce this error. Continued errors may indicate a hardware problem.
Float Error	An error in a floating point math routine occurred.
F-R Error	Frequency-Range incompatibility. The 100kΩ range may not be used with the 100 kHz drive frequency.
Over Load	The Model Z9216 input is overloaded. This can happen transiently as parts are changed or if a part with too small an impedance is measured on the constant drive voltage setting.
Over Range	The impedance is beyond the Model Z9216 measurement ability on the current range. If range hold is active, change to a higher range.
Range Error	Parameter in command is out of allowed range for that command.
Rcl Error	Non-volatile RAM has been corrupted. User calibrations and settings may be lost. If this error occurs frequently, check the battery.
Syn Error	The command syntax is invalid. See the programming section for correct command syntax.

Self-test Errors

These errors may occur during the Model Z9216 self-test. In general, these messages indicate Model Z9216 hardware problems. If the errors occur repeatedly, the unit may have an electrical problem. The messages are listed alphabetically. Also listed is the status value returned by the *TST? command.

Message	Status	Meaning
AD Error	6	The A/D converter failed its test. The test measures 0 V and ±2 VDC.
Bias Error	7	The Model Z9216 internal DC bias source failed its test.
Cal Error	4	The RAM calibration data has become corrupt. The factory values will be reloaded from ROM. This message is not a problem unless it occurs frequently, which could indicate a problem with the battery backup circuits.
Code Err XX	2	The Model Z9216 ROM has a checksum error. XX is the checksum value.
CPU Error	1	The Model Z9216 has detected a problem in its CPU.

Data Error	3	CPU RAM failed a read/write test.
Det Error	6	The square wave multiplier failed its DC rejection test.
Drv Error *i*	7	The output drive circuitry failed its test. *i* is an error code indicating the failure point. <u>*i*</u> <u>error</u> 0 100 Hz amplitude failure 1 120 Hz amplitude failure 2 1 kHz amplitude failure 3 10 kHz amplitude failure 4 100 kHz amplitude failure 5 0.25 V amplitude attenuator failure 6 0.1 V attenuator failure
Freq Error *i*	5	The frequency clock generator failed its test. *i* is an error code indicating the failure point. <u>*i*</u> <u>error</u> 0 100 Hz failure 1 120 Hz failure 2 1 kHz failure 3 10 kHz failure 4 100 kHz failure
Gain Error	8	The instrumentation amplifier failed its gain test. *i* is an error code indicating the failure point. <u>*i*</u> <u>error</u> 0 the ×2 gain failed 1 the ×4 gain failed 2 the ×8 gain failed 3 the ×20 gain failed
Out Error	9	The source impedance selection circuitry failed its test. This error can occur if a part is in the fixture during the test. i is an error code indicating the failure point. <u>*i*</u> <u>error</u> 0 the 100 kΩ range failed 1 the 6.4 kΩ range failed 2 the 400 Ω range failed 3 the 25 Ω range failed

Calibration Errors

These error messages can be generated by the open, short, and standard calibration procedures. If the Model Z9216 fails calibration, try running the procedure again. Repeated failure can indicate a hardware problem. The parameter limits are fixed and are set so that all units should easily calibrate within those limits. The messages are listed alphabetically, also listed is the status value returned by the *CAL? command.

Message	Status	Meaning
Cal Error	1	The measurement is bad due to overload, A/D error, or math error. This error can occur during short circuit, open circuit, and standard resistor calibration.
Cal Error	2	The impedance measured in the short circuit calibration was too large. The Model Z9216 expects the impedance to be < 50 Ω, and the resistance to be less than 10 Ω. Make sure that the fixture has a good low impedance short in it during short circuit calibration.
Cal Error	3	The impedance measured in the open circuit calibration is too small. The Model Z9216 expects the impedance to be > 10 kΩ at all frequencies and ranges. Make sure that there are no parts in the fixture during open circuit calibration. Also, keep hands and other objects away from the fixture during calibration.
Cal Error	4	Standard resistor calibration error. The Model Z9216 expects that standard resistor calibration will not change the value of the internal resistors by more than ± 3 %. Check to be sure that the correct calibration resistor for the range being calibrated is in the fixture.

GPIB Problems

First, make sure that the GPIB interface is installed. Second, the GPIB address of the Model Z9216 must be set to match that expected by the controlling computer. The default GPIB address is 17, so it is a good idea to use this address when writing programs for the Model Z9216. Any address from 0 to 30 may be set using the rear panel switches SW2.

The Model Z9216 will ignore its front panel keypad when Remote Enable (REM) has been asserted by the GPIB. This "REMOTE" state is indicated by the REM LED. To return to LOCAL operation (i.e. to enable the front panel), press the backspace key. Controlling programs may inhibit the ability to return to LOCAL operation by asserting the Local-Lockout state (LLO).

A linefeed character is sent with End or Identify (EOI) to terminate strings from the Model Z9216. Be certain that your GPIB controller has been configured to accept this sequence.

RS-232 Problems

Make sure that the RS-232 baud rate, parity, and word size are set to match that expected by the controlling computer. The default settings are 1200 baud, no parity, 8 bit data. The Model Z9216 always sends two stop bits, and will correctly receive data sent with either one or two stop bits.

When connecting to a PC, use a standard PC serial cable, not a "null-modem" cable. The Model Z9216 is a DCE (Data Communications Equipment) device, and so should be connected with a "straight" cable to a DTE device (Data Terminal Equipment). The "minimum" cable will pass pins 2, 3 and 7. For hardware handshaking, pins 5 and 20 (CTS and DTR) should be passed. Occasionally, pin 6 and 8 (DSR and CD) will be needed; these lines are always asserted by the Model Z9216.

Model Z9216 Test Performance Record

Serial #:	**Date:**
Tested By:	
Equipment Used:	
Model#:	
RH %:	**Temperature:**
Notes:	

FUNCTIONAL TESTS			
Test	**Values**	**Pass**	**Fail**
Front Panel Test			
Self Test			
Drive Voltage			
Resistance Test	24.9 Ω +/- 0.15%		
	402 Ω +/- 0.15%		
	6.34 kΩ +/- 0.15%		
	100.0 kΩ +/- 0.15%		
Capacitance Test	22 nF		

FREQUENCY ACCURACY			
Test Frequency	**Minimum**	**Actual**	**Maximum**
100 Hz +/- 0.01%	99.99 Hz		100.01 Hz
120 Hz +/- 0.01%	119.99 Hz		120.01 Hz
1 kHz +/- 0.01%	999.90 Hz		1000.1 Hz
10 kHz +/- 0.01%	9999.0 Hz		10001.0 Hz
100 kHz +/- 0.01%	99990.0 Hz		100010.0 Hz

AMPLITUDE ACCURACY				
Amplitude	**Frequency**	**Minimum**	**Actual**	**Maximum**
1.0 V_{rms} +/- 2.0%	1 kHz	0.98 V_{rms}		1.02 V_{rms}
1.0 V_{rms} +/- 2.0%	100 Hz	0.98 V_{rms}		1.02 V_{rms}
1.0 V_{rms} +/- 2.0%	120 Hz	0.98 V_{rms}		1.02 V_{rms}
1.0 V_{rms} +/- 2.0%	10 kHz	0.98 V_{rms}		1.02 V_{rms}
1.0 V_{rms} +/- 2.0%	100 kHz	0.98 V_{rms}		1.02 V_{rms}
0.25 V_{rms} +/- 2.0%	1 kHz	0.245 V_{rms}		0.255 V_{rms}
0.1 V_{rms} +/- 2.0%	1 kHz	0.098 V_{rms}		0.102 V_{rms}
Internal Bias				
2.0 VDC +/- 2.0%		1.96 VDC		2.04 VDC

IMPEDANCE ACCURACY			
	Minimum	**Actual**	**Maximum**
1.000 KΩ +/- 0.02%	999.3 Ω		1000.7 Ω

RESISTANCE ACCURACY						
Resistance	**Range**	**Conditions**	**Minimum**	**Actual**	**Maximum**	**Pass/Fail**
10.0Ω	3	1kHz, Series				
25.0Ω	3	1kHz, Series				
25.0Ω	3	10kHz, Series				
25.0Ω	3	100kHz, Series				
100.0Ω	3	1kHz, Series				
100.0Ω	2	1kHz, Series				
400.0Ω	2	1kHz, Series				
400.0Ω	2	10kHz, Series				
400.0Ω	2	100kHz, Series				
1.600KΩ	2	1kHz, Parallel				
1.6000 KΩ	1	1kHz, Parallel				
6.4000 KΩ	1	1kHz, Parallel				
6.4000 KΩ	1	10kHz, Parallel				
6.4000 KΩ	1	100kHz, Parallel				
25.0000 KΩ	1	1kHz, Parallel				
25.0000 KΩ	0	1kHz, Parallel				
100.0000 KΩ	0	1kHz, Parallel				
100.0000 KΩ	0	10kHz, Parallel				
400.0000 KΩ	0	1kHz, Parallel				
*** If the Q Value is Greater Than 0.1, the allowed tolerance must be multiplied by (1+Q).**						

CAPACITANCE ACCURACY						
Capacitance	**Frequency**	**Range**	**Minimum**	**Actual**	**Maximum**	**Pass/Fail**
1.0 nF	1 kHz	0				
1.0 nF	10 kHz	1				
1.0 nF	100 kHz	2				
10.0 nF	100 Hz	0				
10.0 nF	1 kHz	1				
10.0 nF	10 kHz	2				
10.0 nF	100 kHz	2				
100.0 nF	100 Hz	1				
100.0 nF	1 kHz	2				
100.0 nF	10 kHz	2				
100.0 nF	100 kHz	3				
1.0 µF	100 Hz	2				
1.0 µF	1 kHz	2				
1.0 µF	10 kHz	3				
10.0 µF	100 Hz	2				
10.0 µF	1 kHz	3				